AICHE Process Design Group

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AICHE
Organization Management
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Dear Organization Supervisor,

Enclosed is a completed preliminary design study of a grassroots facility to be built near Calvert City, Kentucky. This facility will produce 85MM lbs/yr of Nylon 6,6 from adipic acid and HMDA. The process was designed for 100% as well as a 67% capacity turndown case. A number of simulations were designed, and an economic analysis was completed to determine the optimum process. A Hazard and Operability study (HAZOP) was completed in order to produce the safest design possible. The design group recommends proceeding with detailed design.

If you have any questions on these matters, please contact Rachel Davis at (479) 650-5134.

Sincerely,

Dylan Cannon   Rachel Davis   Raychel Kozik   David Meyer

Dylan Cannon   Rachel Davis   Raychel Kozik   David Meyer

Enclosure: Nylon 6,6 Grassroots Facility Design

AICHE Student Design Competition

Manufacturing Facility for Nylon 6,6

9 March 2017

Group ____________:

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Abstract

The purpose of this project was to develop a preliminary design of a grassroots plant for the production of nylon 6,6 near Calvert City, Kentucky. The yearly production rate of nylon 6,6 was specified at 85 MM lbm/yr. Nylon 6,6 is formed via a polycondensation reaction between adipic acid and hexamethylenediamine. Chains of nylon 6,6 lengthen via step-growth polymerization and the addition of new molecules to the end of each polymer chain.

The preliminary design for the grassroots process involves a pump, two heat exchangers, two reactors, a process vessel, an air cooler, and an extruder. The selected process involves a batch reactor in series with a CSTR in order to maximize polymerization and nylon 6,6 production. The design will produce nylon 6,6 chains with a degree of polymerization of 202. To produce the 85 MM lbm/yr of nylon 6,6, the design will require approximately 55.1 MM lbm of adipic acid, 43.9 MM lbm of HMDA, and 5.2 MM lbm of water each year for the reactants. The nylon 6,6 will be packaged and sold for $1.45 per pound on average. Expected annual revenue for the grassroots plant is expected to be $123.3 million in today's dollars. The design has a total capital investment of approximately $4.03 million, including contingency, fees, and a grassroots factor. Manufacturing costs, including the costs for raw materials, are estimated to be $89.3 million per year. Capital and manufacturing costs are estimated in today's dollars. The process was also designed for a 67% turndown case. This turndown case will cost $59.8 million in manufacturing costs per year and has an expected annual revenue of $82.6 million per year.

Economic evaluation over a ten-year period indicates that the design will have a net present value of $73.36 million at a minimum rate of return of 15%. The expected DCFROR is 5.17%. Construction will begin in Quarter 4 of 2018, and startup is scheduled to take place on June 30, 2019. Upon evaluating the sensitivity, it was found that the sale price of nylon 6,6 has the largest effect on the economics of the design. The proposed design will require 8 plant operators in order to keep the unit running continuously and will cost $775,000 in salary per year. Any safety risks have been accounted for, and a Hazard Operability study was completed.

The design team recommends proceeding with the detailed design phase for the grassroots facility. Equipment layout, including piping and elevation, will need to be completed in order to finalize the equipment sizing and designs. Several assumptions were made in the design process and in the estimation of costs. Therefore, a more thorough design and costing analysis should be completed in order to verify these assumptions during the detailed design.

Introduction

The purpose of this project is to develop the plans for a grassroots plant for the production of nylon 6,6 in Calvert City, Kentucky. Nylon 6,6 was first synthesized in 1935 by Dupont Company [1]. It was the first truly synthetic fiber to be developed for a broad range of applications, and was quickly followed by nylon 6 [2]. Nylon 6,6 has found a wide range of applications due to its strength, stiffness, and heat resistance. Other advantages include its chemical resistance to hydrocarbons, wear resistance, and lubricity. The main limitations of nylon 6,6 include high water absorption and poor resistance to corrosion by strong acids and bases [3]. However, its many strengths have made it a material of interest for a wide variety of industries, particularly the textile industry [4]. It has applications in automotive parts, tubing, and piping, but approximately 75% of the nylon 6,6 produced in the United States goes into the manufacturing of home or clothing textiles [5]. From its initial inception, nylon has played a large role in the clothing industry. First developed as an alternative for silk stockings, it soon found its place in every type of clothing, leaving a noticeable mark on the industry. Today, it can be found in a wide variety of everyday items and has permeated the textile industry. In 2014, combined production of nylon 6,6 and nylon 6 topped 7.2 million tons, and the market continues to grow [6]. This combined polyamide market is currently estimated at 25.14 billion USD, with projections to grow to 30.76 billion USD in the next five years [7]. This market growth, combined with the growing uses for nylon 6,6 products, yields a convincing argument for the need to invest in new production facilities.

Nylon 6,6 is synthesized via a polycondensation reaction between hexamethylenediamine (HMDA) and adipic acid (ADA). HMDA is a diamine composed of a six-carbon chain with amino groups at each end [8]. Adipic acid is an organic compound consisting of a six-carbon chain with carboxylic acid groups at each end [9]. Nylon 6,6 itself has a monomeric formula of $C_{12}H_{22}N_2O_2$, and lengthens via step-growth polymerization and the addition of new molecules to each end of the polymer chain [10]. The overall reaction is shown below in **Figure 1.**

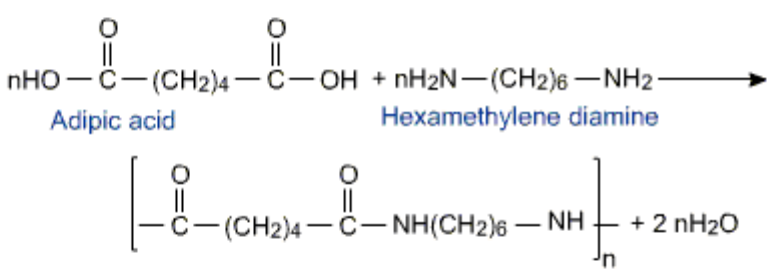


Figure 1: Overall Reaction for Nylon 6,6 Production [11]

Initially, the two reactants combine to form a nylon 6,6 salt with stoichiometric equivalents. The nylon salt is then sent to a reactor where the process of step-growth polymerization begins. Then, aqueous nylon 6,6 is sent to a second reactor where water is removed. The removal of water drives the reaction to completion and leads to further lengthening of the polymer chain. Increased levels of water removal yield higher molecular-weight nylon. This molten nylon is then ready for further processing into pellets or fibers. The resulting water side stream can be treated and released.

Production will take place at a grassroots plant in the Calvert City, Kentucky area. The Calvert City area is home to a multitude of chemical processing plants of various sizes, offering a community familiar to interacting with processing plants. In addition, the presence of many chemical plants and refineries creates a sense of scientific community among the businesses in the area. At this time, the production rate has been specified at 85 MM lbm/year. This system has been designed for a full production case, as well as a turndown case of 67% capacity.

For this project, a two-reactor scheme has been developed. The first of the two reactors is a batch reactor, and the second is a CSTR. A block-flow diagram of this process can be seen below in **Figure 2.**

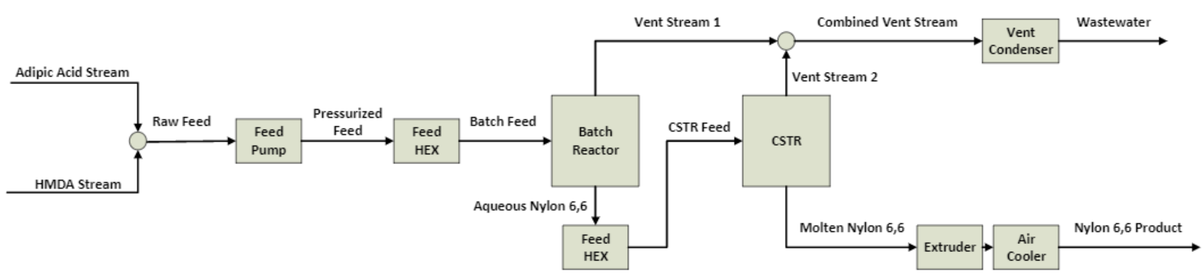


Figure 2: Block-Flow-Diagram for Batch/CSTR Process

This particular scheme was chosen for its economic attractiveness and the ability to develop a simple and effective safety strategy for the process. Also considered were PFR/CSTR and CSTR/CSTR reactor schemes. However, both schemes were rejected for this project. The CSTR/CSTR scheme yielded a nylon 6,6 product below the appropriate molecular weight and degree of polymerization specifications needed for sale. The PFR/CSTR scheme yielded high-quality nylon 6,6, but was less economically attractive, especially for the turndown case. In addition, the Batch/CSTR process allowed for a simpler safety strategy. These economic and safety factors are described in more detail in subsequent sections of this report.

In developing the plans for this nylon 6,6 production plant, a variety of environmental and safety factors were considered. The raw materials from this process, HMDA and adipic acid, can cause irritation to the skin and eyes upon contact. In addition, inhalation of dust from these materials can cause irritation of respiratory tracts. Both HMDA and adipic acid are slightly flammable, but only at elevated temperatures. Steps to mitigate these hazards were taken in order to reduce the risk of exposure. Nylon 6,6 itself can also irritate the eyes or lungs, but it is not considered to be a major skin irritant. Thermal decomposition of nylon can lead to toxic vapors. Therefore, processes were kept at temperatures below the decomposition temperature of nylon 6,6. The water byproduct stream of the process must be put through wastewater treatment systems before being released to the environment in order to prevent the release of any remaining raw materials or product. A HAZOP analysis revealed the importance of controlling the temperature of the process, as well as maintaining the integrity of the streams. This project report and accompanying appendix will elaborate on the chosen process, as well as the equipment needed to execute the process. In addition, this report will investigate the economic and safety factors considered when developing this system and deciding on the final process design.

Process Flow Diagram and Material Balances:

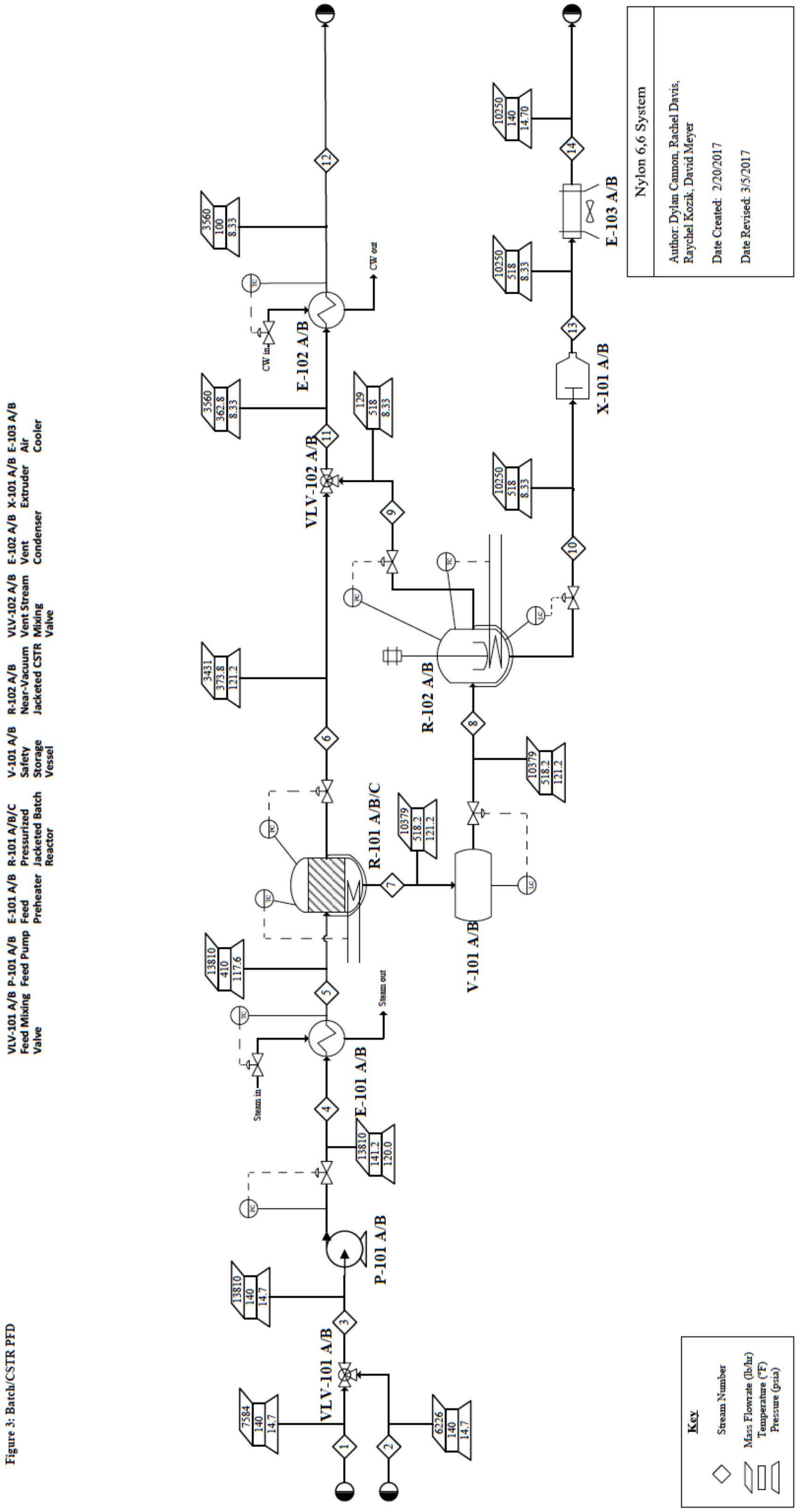


Figure 3: Batch/CSTR PFD

Figure 4 : 100% Batch/CSTR Design Stream Table

Stream Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Stream Description	Adipic Acid Raw Feed	HMDA Raw Feed	Raw Mixed Feed	Pressurized Feed	Feed to Batch Reactor	Vent Stream 1	Aqueous Nylon	Feed to CSTR	Vent Stream 2	Nylon 6,6	Combined Vent Stream	Wastewater Stream	Extruded Nylon 6,6	Cooled Nylon 6,6 Pellets
Temperature (°F)	140.0	140.0	140.0	141.2	410.0	373.8	518.2	518.2	518.0	518.0	362.8	100.0	518.0	140.0
Pressure (psia)	14.70	14.70	14.70	120.00	117.57	121.24	121.24	121.24	8.33	8.33	8.33	14.70	8.33	14.70
Vapor Fraction	0	0	0	0	0	1	0	0	1	0	1	0	0	0
Enthalpy Flow (Btu/hr)	-2.52E+07	-9.22E+06	-3.44E+07	-3.44E+07	-3.20E+07	-1.91E+07	-5.83E+06	-5.83E+06	-7.17E+05	-5.00E+06	-1.99E+07	-2.39E+07	-5.00E+06	-7.26E+06
Density (lbm/ft^3)	69.90	54.25	61.87	61.83	52.66	0.26	53.92	53.92	0.01	54.06	0.02	61.13	54.06	61.02
Mass Flow (lbm/hr)	7584.3	6225.5	13809.8	13809.8	13809.8	3431.0	10378.7	10378.7	128.7	10250.0	3559.8	3559.8	10250.0	10250.0
Component Mass Flow (lbm/hr)														
Nylon 6,6	0.0	0.0	0.0	0.0	0.0	0.0	10252.9	10252.9	0.0	10241.9	0.0	0.0	10241.9	10241.9
Adipic Acid	6630.9	0.0	6630.9	6630.9	6630.9	0.5	1.8	1.8	0.0	0.5	0.6	0.6	0.5	0.5
Hexamethylenediamine	0.0	5273.0	5273.0	5273.0	5273.0	40.6	0.4	0.4	0.0	0.0	40.6	40.6	0.0	0.0
Water	953.3	952.5	1905.8	1905.8	1905.8	3390.0	123.5	123.5	128.7	7.6	3518.6	3518.6	7.6	7.6

Figure 5 : 67% Batch/CSTR Design Stream Table

Stream Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Stream Description	Adipic Acid Raw Feed	HMDA Raw Feed	Raw Mixed Feed	Pressurized Feed	Feed to Batch Reactor	Vent Stream 1	Aqueous Nylon	Feed to CSTR	Vent Stream 2	Nylon 6,6	Combined Vent Stream	Wastewater Stream	Extruded Nylon 6,6	Cooled Nylon 6,6 Pellets
Temperature (°F)	140.0	140.0	140.0	141.2	410.0	373.8	518.2	518.2	518.0	518.0	362.8	100.0	518.0	140.0
Pressure (psia)	14.70	14.70	14.70	120.00	117.57	121.24	121.24	121.24	8.33	8.33	8.33	14.70	8.33	14.70
Vapor Fraction	0	0	0	0	0	1	0	0	1	0	1	0	0	0
Enthalpy Flow (Btu/hr)	-1.68E+07	-6.15E+06	-2.29E+07	-2.29E+07	-2.14E+07	-1.28E+07	-3.88E+06	-5.83E+06	-4.78E+05	-3.34E+06	-1.32E+07	-1.60E+07	-3.34E+06	-4.84E+06
Density (lbm/ft3)	69.90	54.25	61.87	61.83	52.66	0.26	53.92	53.92	0.01	54.06	0.02	61.13	54.06	61.02
Mass Flow (lbm/hr)	5056.2	4150.3	9206.5	9206.5	9206.5	2287.4	6919.1	10378.7	85.8	6833.3	2373.2	2373.2	6833.3	6833.3
Component Mass Flow (lbm/hr)														
Nylon 6,6	0.0	0.0	0.0	0.0	0.0	0.0	6835.3	10252.9	0.0	6827.9	0.0	0.0	6827.9	6827.9
Adipic Acid	4420.6	0.0	4420.6	4420.6	4420.6	0.4	1.2	1.8	0.0	0.4	0.4	0.4	0.4	0.4
Hexamethylenediamine	0.0	3515.3	3515.3	3515.3	3515.3	27.0	0.3	0.4	0.0	0.0	27.1	27.1	0.0	0.0
Water	635.6	635.0	1270.6	1270.6	1270.6	2260.0	82.4	123.5	85.8	5.0	2345.8	2345.8	5.0	5.0

Process Description

Reactor Modeling:

For the purpose of this preliminary design, Aspen Plus was used to model the polymerization of nylon 6,6 in both reactors. A step-growth polymerization model was used in order to represent the addition of monomers to the polymer chain. This model includes 12 equations to account for the condensation reactions, as well as the addition of HMDA and ADA to the ends of the polymer chain. This model works by separating available HMDA and ADA into repeat units and end units. By separating these components, the model can differentiate between segments of the reactants available for polymerization. **Figure 6**, shown below, shows the components used in the reactor models, including their common names and structures.

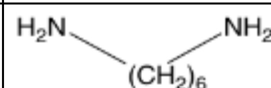
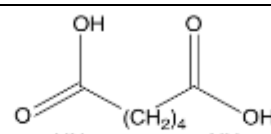
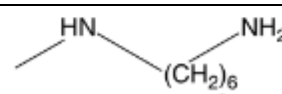
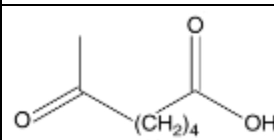
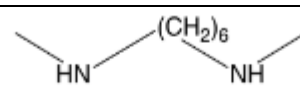
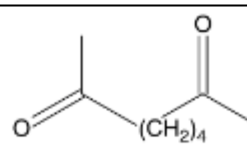
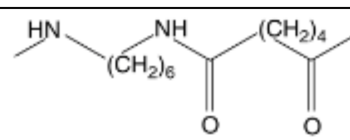
Model Name	Common Name	Trivial Formula	Molecular Structure
H2O	Water	H_2O	H2O
HMDA	Hexamethylenediamine	$C_6H_{16}N_2$	
ADA	Adipic Acid	$C_6H_{10}O_4$	
HMDA-E	HMDA end	$C_6H_{15}N_2$	
ADA-E	ADA end	$C_6H_9O_3$	
HMDA-R	HMDA repeat unit	$C_6H_{14}N_2$	
ADA-R	ADA repeat unit	$C_6H_8O_2$	
NYLON66	Nylon 6,6	$C_{12}H_{22}N_2O_2$	

Figure 6: Components Used in Reactor Model [12]

These components are combined in the model in order to accurately depict the process taking place in the reactor. The 12 unique reactions combine to form the overall reaction described by

Figure 1 in the Introduction section. Four reactions account for condensation, four equations account for polymerization, and four reactions account for reverse condensation. These 12 reactions can be seen below in **Figure 7.**

Reaction Type	Reactants	⇒	Products
Condensation	HMDA + ADA	⇒	H2O + HMDA-E + ADA-E
Condensation	HMDA + ADA-E	⇒	H2O + HMDA-E + ADA-R
Condensation	HMDA-E + ADA	⇒	H2O + HMDA-R + ADA-E
Condensation	HMDA-E + ADA-E	⇒	H2O + HMDA-R + ADA-R
Polymerization	HMDA + ADA-E + HMDA-R	⇒	HMDA-E + HMDA-E + ADA-E
Polymerization	HMDA + ADA-R + HMDA-R	⇒	HMDA-E + HMDA-E + ADA-R
Polymerization	HMDA-E + HMDA-E + ADA-E	⇒	HMDA-R + ADA-E + HDMA
Polymerization	HMDA-E + HMDA-E + ADA-R	⇒	HMDA-R + ADA-R + HMDA
Rev-Condensation	H2O + ADA-E + HMDA-E	⇒	ADA + HMDA
Rev-Condensation	H2O + ADA-E + HMDA-R	⇒	ADA + HMDA-E
Rev-Condensation	H2O + ADA-R + HMDA-E	⇒	ADA-E + HMDA
Rev-Condensation	H2O + ADA-R + HMDA-R	⇒	ADA-E + HMDA-E

Figure 7: Model Reactions Used in Aspen Plus Simulation [12]

Forward reaction rate data was obtained using correlations described in Kumar, et. Al [13, 14] using data given by Ogata, et. al, 1961 [15, 16]. These correlations were deemed appropriate for this model because they accounted for the batch-style reactor used in the process. These correlations took into consideration the temperature of the reactor, as well as the presence of water in the feed stream. Because the process has a 99.92% conversion and is designed using conditions that result in effective removal of the majority of the water, the reaction is assumed to be irreversible. This assumption was made because the removal of water drives the reaction to the right far enough to neglect the reverse reaction. Rate constants for all considered cases are shown in **Figure 8** below.

Reactor:	Rate Constant: (ft^3/lbmol-hr)
R-101	25200
R-102	50.4

Figure 8: Rate Constant Data for All Cases

The rate of the reaction for Reactor R-101 is modeled by **Equation [1]** below.

$$r_A = k\,[ADA][HMDA]\exp\left(\frac{-2500}{RT}\right) \qquad [1]$$

Where r_A = reaction rate, lbmol/ft^3 -hr.

[ADA] = concentration of adipic acid, lbmol/ft^3

[HMDA] = concentration of hexamethylenediamene, lbmol/ft^3

R = ideal gas constant, J/mol-K

T = reactor temperature, K

k = rate constant, ft^3/lbmol-hr

The rate of the reaction for Reactor R-102 is modeled by **Equation [2]** below.

$$r_A = k[H_2O]^2\exp\left(\frac{-2500}{RT}\right) \qquad [2]$$

Where r_A = reaction rate, lbmol/ft^3-hr

[H_2O] = concentration of water, lbmol/ft^3

R = ideal gas constant, J/mol-K

T = reactor temperature, K

k = rate constant, ft^3/lbmol-hr

Batch Process Description:

Figure 3 on **Page 7** displays a full PFD for the chosen batch reactor process. In addition, stream summary tables for both a full capacity case and a 67% capacity turndown case can be found in **Figure 4** on **Page 8** and **Figure 5** on **Page 9**, respectively. The process begins with the mixing of ADA (Stream 1) and HMDA (Stream 2) at a mixing valve (VLV-101 A/B) to form a mixed reactant stream (Stream 3). This stream is approximately 13.8 wt% water, and is the location of the beginning of the reaction to form the nylon 6,6 salt. The mixed feed stream is pressurized via P-101 A/B and heated to 410 °F via a steam-powered heat exchanger (E-101 A/B). This heated and pressurized feed is delivered to R-101 A/B/C. R-101 A/B/C is a batch reactor heated with an electric jacket. In this reactor, the nylon salt/reactant mixture reacts further to form an aqueous nylon stream. This aqueous nylon mixture (Stream 7) is then sent to a holding tank (V-101 A/B) before entering a second reactor (R-102 A/B). A vent stream (Stream 6) allows for the removal of vapor from R-101 A/B/C. In the second reactor (R-102 A/B), the aqueous nylon mixture (Stream 8) is further heated in order to remove as much water as possible. The removal of water vapor via the vent stream (Stream 9) pushes the reaction to the right, thus lengthening the polymer chain and increasing the quality of the product. The vent stream (Stream 9) is combined with the vent stream from R-101 A/B/C (Stream 6) at VLV-102 A/B and cooled to 100℉ via E-102 A/B. This cooled combined vent water stream (Stream 12) is then sent through wastewater treatment and released. Heat integration was considered, but it was found that Stream 12 does not contain enough energy to be used to heat the feed stream. The molten nylon 6,6 stream (Stream 10) is then sent to an extruder to be pelletized and cooled via E-103 A/B before packaging and shipping. Due to the potential dust production and tendency of nylon 6,6 to degrade when exposed to water and heat, this plant was designed to send the finished pellets directly to packaging and shipping rather than to a storage container or vessel.

The process will require 55.1 MM lbm/yr of ADA, 43.9 MM lbm/yr of HMDA, and 5.2 MM lbm/yr of feed water in order to produce the required 85 MM lbm/yr of nylon 6,6. The degree of polymerization will be approximately 202. Further details on individual pieces of equipment and reasons for equipment choices are discussed in the subsequent Equipment Lists and Equipment Specifications sections.

Alternative Processes:

In addition to the chosen batch reactor process, an alternative reactor setup was also considered. This setup featured a plug-flow reactor as R-101 rather than a batch reactor, followed with a CSTR for R-102. A block-flow diagram for this process can be seen below in **Figure 9.**

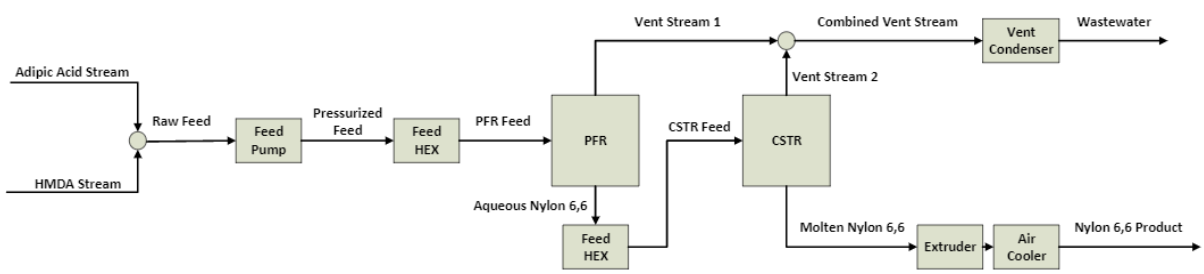


Figure 9: Block-Flow Diagram of PFR/CSTR Process

A PFD for this process can be found in **Figure 11** on **Page 15**. Stream Summary Tables for this alternative process can be found in **Figure 12** on **Page 16** for a full capacity case and **Figure 13** on **Page 17** for a 67% capacity turndown case. This process functions in a similar way to the original batch process, with the only difference being the replacement of the batch reactor with a plug-flow reactor. Though this process is a viable option, the batch process was found to be more economically attractive and an overall safer process than the PFR process. These points will be discussed further in this report in the Economic Analysis and Safety sections.

A third process was considered in initial research stages but was rejected early in the design process. This reactor scheme included two CSTRs in series to create the nylon 6,6 product.

Though this design could be economically attractive, it yields a much lower molecular weight product. This product is below the accepted degree of polymerization standards for nylon 6,6 and would not be of a high enough quality to sell for profit. A block-flow diagram of this process can be found below in **Figure 10.**

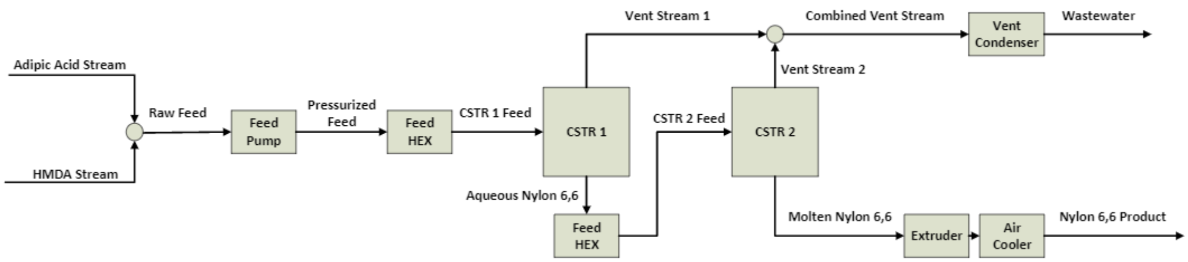


Figure 10: Block-Flow Diagram of CSTR/CSTR Process

The final Batch/CSTR process was chosen for its combination of economic attractiveness as determined by Net Present Value (NPV) incremental analysis and Discounted Cash Flow Rate of Return (DCFROR) comparison, as well as its ability to remain profitable under turndown conditions. In addition, this process has fewer inherent safety risks, and is thought to be the best choice for this plant. These points will be investigated in more detail throughout this report.

Figure 11: PFR/CSTR PFD

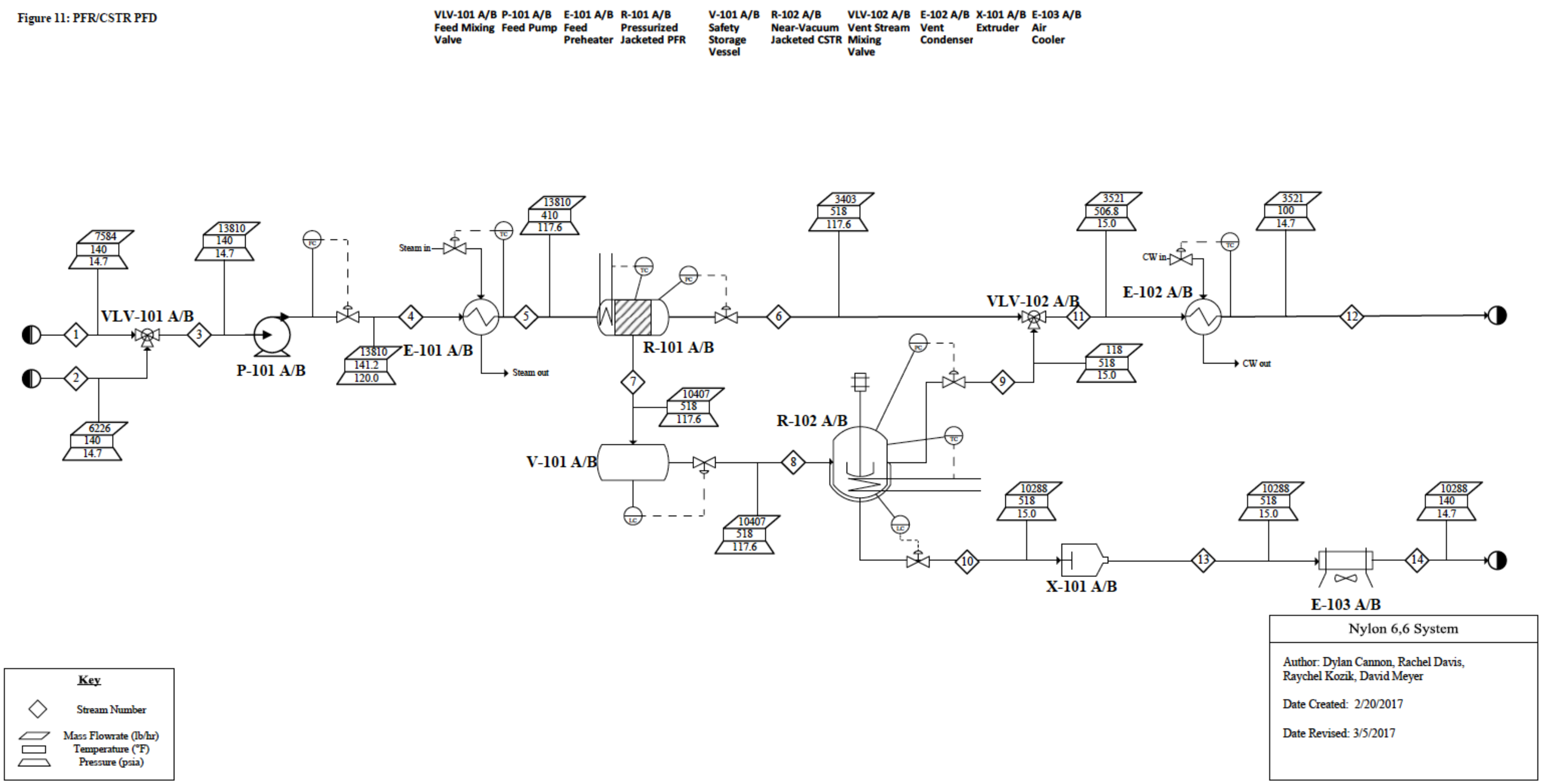


Figure 12 : 100% PFR/CSTR Design Stream Table

Stream Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Stream Description	Adipic Acid Raw Feed	HMDA Raw Feed	Raw Mixed Feed	Pressurized Feed	Feed to Batch Reactor	Vent Stream 1	Aqueous Nylon	Feed to CSTR	Vent Stream 2	Nylon 6,6	Combined Vent Stream	Wastewater Stream	Extruded Nylon 6,6	Cooled Nylon 6,6 Pellets
Temperature (°F)	140.0	140.0	140.0	141.2	392.0	518.0	518.0	518.0	518.0	518.0	506.9	100.0	518.0	140.0
Pressure (psia)	14.70	14.70	14.70	120.00	117.57	117.57	117.57	117.57	14.99	14.99	14.99	14.70	14.99	14.70
Vapor Fraction	0	0	0	0	0	1	0	0	1	0	1	0	0	0
Enthalpy Flow (Btu/hr)	-2.52E+07	-9.22E+06	-3.44E+07	-3.44E+07	-3.22E+07	-1.90E+07	-5.76E+06	-5.76E+06	-6.63E+05	-5.00E+06	-1.96E+07	-2.39E+07	-5.00E+06	-7.63E+06
Density (lbm/ft^3)	69.90	54.25	61.87	61.83	53.34	0.21	53.89	53.89	0.03	54.02	0.03	61.27	54.02	60.99
Mass Flow (lbm/hr)	7584.3	6225.5	13809.8	13809.8	13809.8	3403.0	10406.7	10406.7	119.0	10287.7	3522.1	3522.1	10287.7	10287.7
Component Mass Flow (lbm/hr)														
Nylon 6,6	0.0	0.0	0.0	0.0	0.0	0.0	10285.1	10285.1	0.0	10273.7	0.0	0.0	10273.7	10273.7
Adipic Acid	6630.9	0.0	6630.9	6630.9	6630.9	0.1	1.0	1.0	0.0	0.1	0.1	0.1	0.1	0.1
Hexamethylenediamine	0.0	5273.0	5273.0	5273.0	5273.0	2.2	0.8	0.8	0.1	0.1	2.3	2.3	0.1	0.1
Water	953.3	952.5	1905.8	1905.8	1905.8	3400.7	119.9	119.9	119.0	13.7	3519.6	3519.6	13.7	13.7

Figure 13 : 67% PFR/CSTR Design Stream Table

Stream Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Stream Description	Adipic Acid Raw Feed	HMDA Raw Feed	Raw Mixed Feed	Pressurized Feed	Feed to Batch Reactor	Vent Stream 1	Aqueous Nylon	Feed to CSTR	Vent Stream 2	Nylon 6,6	Combined Vent Stream	Wastewater Stream	Extruded Nylon 6,6	Cooled Nylon 6,6 Pellets
Temperature (°F)	140.0	140.0	140.0	141.2	392.0	518.0	518.0	518.0	518.0	518.0	506.9	100.0	518.0	140.0
Pressure (psia)	14.70	14.70	14.70	120.00	117.57	117.57	117.57	117.57	14.99	14.99	14.99	14.70	14.99	14.70
Vapor Fraction	0	0	0	0	0	1	0	0	1	0	1	0	0	0
Enthalpy Flow (Btu/hr)	-1.68E+07	-6.15E+06	-2.29E+07	-2.29E+07	-2.15E+07	-1.26E+07	-3.84E+06	-3.84E+06	-4.42E+05	-3.33E+06	-1.31E+07	-1.60E+07	-3.33E+06	-5.09E+06
Density (lbm/ft3)	69.90	54.25	61.87	61.83	53.34	0.21	53.89	53.89	0.03	54.02	0.03	61.27	54.02	60.99
Mass Flow (lbm/hr)	5056.2	4150.3	9206.5	9206.5	9206.5	2268.7	6937.8	6937.8	79.4	6858.4	2348.1	2348.1	6858.4	6858.4
Component Mass Flow (lbm/hr)														0
Nylon 6,6	0.0	0.0	0.0	0.0	0.0	0.0	6856.7	6856.7	0.0	6849.1	0.0	0.0	6849.1	6849.1
Adipic Acid	4420.6	0.0	4420.6	4420.6	4420.6	0.1	0.7	0.7	0.0	0.1	0.1	0.1	0.1	0.1
Hexamethylenediamine	0.0	3515.3	3515.3	3515.3	3515.3	1.5	0.5	0.5	0.1	0.1	1.5	1.5	0.1	0.1
Water	635.6	635.0	1270.6	1270.6	1270.6	2267.1	79.9	79.9	79.3	9.1	2346.4	2346.4	9.1	9.1

Energy Balance and Utility Requirements

Heat Exchangers:

As described in the previous section, this process design requires multiple heat exchangers in order to meet the necessary temperatures needed for reaction, wastewater treatment, and packaging. The first of these is Heater E-101, which is necessary to heat the nylon salt solution (Stream 4) to 410 °F. This temperature is below the temperature needed for the first reactor. It was found that if we heated the reactants too much prior to entering the reactor, we would have a reaction taking place in the piping. This would result in a blocked pipe and loss of conversion. Through a sensitivity analysis, we found that 410 °F is the optimum temperature for Stream 4 prior to entering the reactor. This temperature maximizes conversion and minimizes energy costs.

High pressure steam is used as the heating agent because of its cost effectiveness. The heat requirement to heat Stream 4 from 141 °F to 410 °F is 2.34 MM Btu/hr. This value comes from the Aspen Plus simulation. High Pressure steam will provide the necessary heat duty needed to make this heat exchange work. The high pressure steam is condensing and thus does not undergo a temperature change. Using **Equation [3]**, we are able to calculate the necessary steam flow rate to obtain the correct heat duty.

$$\dot{m} = \frac{Q}{\lambda} \qquad [3]$$

Where $\dot{m}$ = steam flow rate, lbmol/hr
Q = heat duty, Btu/hr
λ = latent heat of vaporization for high pressure steam (720 Btu/lbm at 600 psig [17])

From this equation, the steam flowrate has been calculated to be 3250 lbm/hr.

Stream 11 is the combined water vent stream from both of the reactors. This stream is at a temperature of 363 °F and is too high to allow for proper wastewater disposal. Thus, it will need to be cooled down. To meet these necessary requirements, the wastewater will be cooled down to 100 °F [18]. This will take place in Cooler E-102. From the Aspen Plus simulation, Stream 11 will have to release 4.08 MM Btu/hr of heat for the wastewater stream to be cooled from 363 °F to 100 °F. Cooling water at 87 °F will absorb the 4.08 MM Btu/hr of heat and will subsequently increase its temperature to 100 °F. The amount of cooling water required to transfer this heat duty can be calculated by **Equation [4].**

$$Q = \dot{m}C_p\Delta T \qquad [4]$$

Where: Q = heat duty, Btu/hr

$\dot{m}$ = mass flow rate of cooling water, lbm/hr

C_p = average heat capacity, Btu/lbm-°F

ΔT = change in cooling water temperature, °F

Using an average temperature of 93.5 °F, the heat capacity of water is equal to 1.01 Btu/(lb °F). From **Equation [4]**, it was calculated that 310,739 lbm/hr of cooling water is needed.

Cooler E-103 is an electric air cooler that will be used to cool the nylon 6,6 product from 518 °F to 140 °F. To do this, the Aspen Plus simulation estimates that 2.26 MM Btu/hr will be required, or 662 kW of electricity. The outlet temperature of 140 °F was chosen as the temperature at which the air cooler would shut off. The design group chose 140°F based on heuristics found in Turton, et al [19]. The nylon 6,6 will continue to cool down unaided until it reaches ambient temperature. Using **Equation [4]**, with the heat capacity of air being 0.25 Btu/(lb °F) and an estimated approach temperature of 40°F, [19] it was calculated that the flowrate of air will be roughly 226 M lbm/hr.

Reactors:

The polycondensation reaction that generates nylon 6,6 is slightly endothermic and needs to be maintained at a constant temperature of 518 °F to ensure maximum conversion. Therefore, both the batch and continuously stirred tank reactors will need to contain a heat jacket. For both reactors, the temperatures need to be maintained at temperatures in excess of the temperature of high pressure steam. Therefore, high pressure steam cannot be used to maintain the temperatures in these reactors. Electric heaters will work best for this process instead. The design team made the decision to use these high temperatures because they will result in conversions close to 100%. As a result, only trace amounts of ADA and HMDA are found in the product and vent streams. This allows the process to conserve mass and eliminate wastes.

The feed for Reactor R-101 (Stream 5) is at a temperature of 410 °F and a pressure of 117.6 psia. When it enters Reactor R-101, it will need to be heated to and maintained at 518 °F for the polycondensation reaction to occur. From the energy balance that takes place in Aspen Plus, 726 M Btu/hr of energy will need to be transferred to successfully heat Stream 5 to 518 °F and maintain this temperature throughout the time the reaction is taking place in the reactor. As stated above, an electric heater will be used to provide the 726 M Btu/hr of energy required. Thus, 213 kW of electricity will be needed.

Reactor R-102 will also require a reactor jacket to maintain a constant temperature of 518 °F. This temperature is required in order to maximize conversion for the CSTR. From the energy balance in Aspen Plus, 106 M Btu/hr of energy, or 31 kW, is required to heat the reactor and will also be provided by an electric heater.

Pumps:

Only one pump is needed in this design to produce the optimum pressures for nylon 6,6 production. Pump P-101 is used to pressurize the mixed feed of ADA, HMDA, and water. Stream 3 enters Pump P-101 at a pressure of 14.7 psia, and is pumped to a pressure of 120 psia when it leaves the pump as Stream 4. This will require 5.6 kW of electricity.

Extruders:

The extrusion unit is responsible for forming nylon 6,6 pellets from the nylon 6,6 product stream. The product stream is at 518 °F, and exits at atmospheric pressure, where it will be subsequently cooled by Air Cooler E-103. The extruder will require 55 kW of electricity to produce the nylon 6,6 pellets. It is labeled X-101.

A summary of the utility requirements for the two heat exchangers can be found below in **Figure 14**, and a summary of the utility requirements for the reactors, pump, and extruder can be found below in **Figure 15.**

Heat Exchanger	Energy Requirements (Btu/hr)	Steam Flowrate (lbm/hr)	Cooling Water Flowrate (lbm/hr)	Electricity Requirements (kW)
E-101	2,336,000	3250	-	-
E-102	4,080,000	-	310739	-
E-103	2,260,000	-	-	662

Figure 14: Heat Exchanger Utility Requirement Summary

Process Unit	Energy Requirement (Btu/hr)	Electricity Requirement (kW)
R-101	726,000	213
R-102	106,000	31
P-101	-	3.6
X-101	-	55

Figure 15: Reactors, Pump, and Extruder Utility Requirement Summary

The design team was also tasked with designing the process equipment for a 67% turndown case. While equipment sizing will stay the same, energy and utility requirements will be affected. The same equations and calculations are used for the turndown case, and energy requirements and flow rates are decreased by 33%. **Figures 16** and **17** summarize the 67% turndown utility requirements for heat exchangers and the reactors, pump, and extruder, respectively.

Heat Exchanger	Energy Requirements (Btu/hr)	Steam Flowrate (lbm/hr)	Cooling Water Flowrate (lbm/hr)	Electricity Requirements (kW)
E-101	1,570,000	2178	-	
E-102	2,730,000	-	208,195	
E-103	1,510,000			444

Figure 16: Heat Exchanger Turndown Utility Requirement Summary

Process Unit	Energy Requirement (Btu/hr)	Electricity Requirement (kW)
R-101	486,000	142
R-102	71,000	21
P-101	-	2.4
X-101	-	55

Figure 17: Reactors, Pump, and Extruder Turndown Utility Requirement Summary

Equipment List and Unit Descriptions:

Figure 18 is a summary equipment list for this process. Each of these units will be explained in detail in the upcoming subsections.

Unit Number	Unit Type	Brief Function	MOC	Size	Design Temperature	Design Pressure
P-101 A/B	Centrifugal Pump	Increase nylon salt feed pressure	CS	10 hp	140 °F	170 psia
E-101 A/B	Heater	Feed Heater	CS/SS	91.4 ft^2	489 °F	170 psia
E-102 A/B	Cooler	Vent Cooler	CS/SS	1074 ft^2	374 °F	64.7 psia
E-103 A/B	Air Cooler	Product cooler	CS	162	518 °F	64.7 psia
R-101 A/B/C	Batch Reactor	Convert Feed to Nylon Salt	CS	437.1 ft^2	518 °F	170 psia
R-102 A/B	CSTR	Convert Nylon Salt to Nylon 6,6	CS	548.6 ft^3	518 °F	58.3 psia
V-101 A/B	Process Vessel	Holding Tank for Nylon salt	CS	64 ft^3	518 °F	170 psia
X-101 A/B	Extruder	Produce Nylon 6,6 pellets	Nitrided Steel	337.5 ft^2	518 °F	170 psia

Figure 18: Equipment List Summary

Pumps:

A summary of the pump is given by **Figure 19** below.

Pump P-101			
ΔP	105.3	Q (ft^3/hr)	3339
$P_{discharge}$ (psia)	120	$\dot{m}$ (lbm/hr)	13,810
$P_{Suction}$ (psia)	14.7	η_{motor}	0.86
P_{Design} (psia)	170	η_{Pump}	0.45
ρ_{Fluid} (lbm/ft^3)	61.84	Hydraulic Hp	3.42
ρ_{Water} (lbm/ft^3)	62.37	Brake Hp	7.51
Specific Gravity	0.992	Purchased Hp	8.73

Figure 19: Pump P-101 Summary Design Table

A sensitivity analysis was completed in Aspen Plus to determine the optimum pressure required for the process. **Figure 20** shows that that the degree of polymerization maximizes around a design pressure of 155 psig. For this reason, we chose to use P-101 to increase the feed pressure to 155 psig, or 170 psia. The feed streams are entirely liquid, and therefore a pump was chosen over a compressor. The design team chose to use a centrifugal pump because of its versatility in flow capacity. The centrifugal pump allows for a greater range of flow rates than a positive displacement or reciprocating pump. This will allow us to be a lot more flexible in regards to any changes in flow rate required. Three options were considered for the centrifugal pump: a standard pump with axial flow, a turbine pump with mixed flow, and a propeller pump with axial flow. A standard centrifugal pump was chosen because it is the only centrifugal pump able to handle the 245 ft of pressure head required. The flow streams are also not abrasive or contain a high solid content [20].

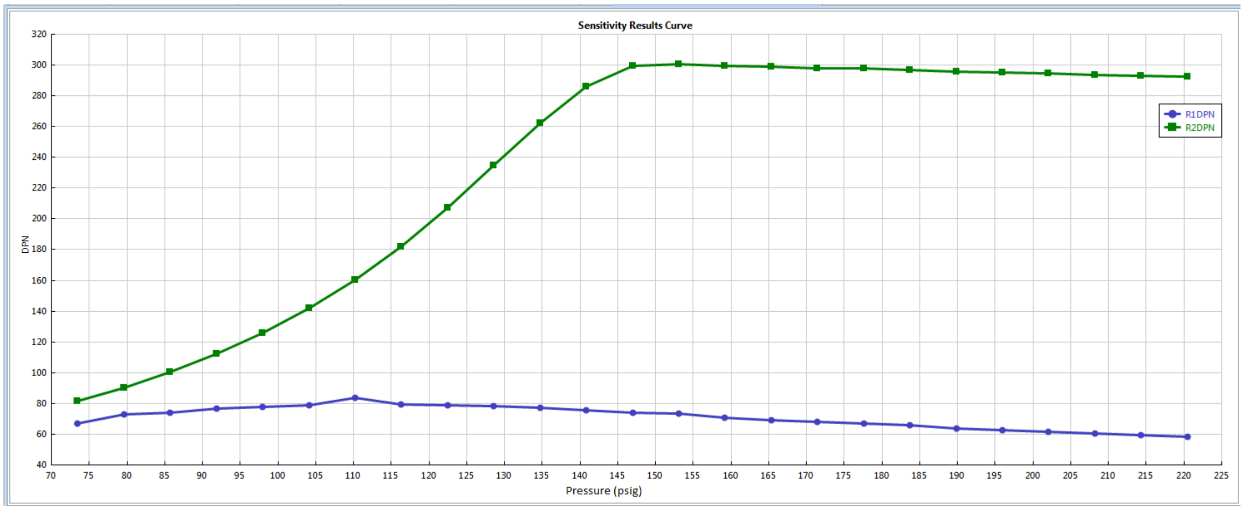


Figure 20: Pressure Sensitivity analysis

The Aspen Plus simulation program was used to assist in pump design. Aspen calculated the pressure head, hydraulic horsepower, and brake horsepower based on the volumetric flowrate and pressure change in the pump. Aspen Plus estimated the pump efficiency of 0.45 based on the flow conditions and fluid in the process. Using the Aspen Plus estimated brake horsepower of 7.51, we were able to use **Figure 21** to determine that the motor efficiency is approximately 0.86. Dividing the brake horsepower by the motor efficiency results in a purchased horsepower of 8.73. Thus a 10 horsepower electric motor is required for pump P-101.

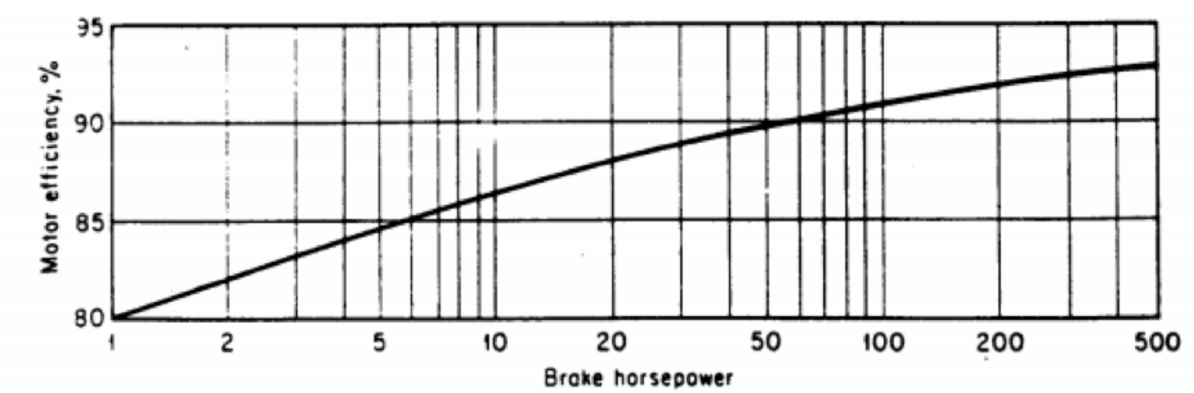


Figure 21: Centrifugal Pump Motor Efficiency [21]

The material of construction (MOC) for pump P-101 is carbon steel. Carbon steel is the least expensive and thus the most economic choice for material of construction. The Nylon salt feed stream is not corrosive to carbon steel, and carbon steel is capable of handling the pressures and temperatures that the pump will encounter. One spare pump will also be required and costed for in order to avoid a shutdown if there should be any maintenance requirements for the pump. The Pump Specification sheet is found on **Page 35** of this report, and the costing summary for this piece of equipment can be found on **Page 75**.

Heat Exchangers:

Three different heat exchangers were used for this process. E-101 is used to heat the nylon salt feed stream, E-102 is used to cool the combined water vent stream at the end of the process, and E-103 is used to cool the nylon 6,6 product. Heat exchangers E-101 and E-102 are basic countercurrent flow shell and tube heat exchangers. The design team chose this model because of its ease of design and heat transfer capabilities [21].

The shell and tube configuration allows us to minimize the heat transfer area required, while the countercurrent configurations allows for maximum heat transfer. For both E-101 and E-102, Carbon steel was chosen as the MOC for the shell because it is inexpensive and we do not have to worry about any corrosion in the shell due the nylon salt solution. Stainless steel was chosen as the tube material because water and steam have been found to be quite corrosive on carbon steel heat exchanger tubes [22]. Stainless steel is much more resistant to fouling caused by water, and should last much longer in the field [22]. Cooler E-103 is an air cooler connected with the nylon 6,6 extruder. Carbon steel was chosen as its MOC because air is not corrosive to carbon steel, and carbon steel is the most cost effective. **Figure 22** is a design summary table for Heater E-101.

Heater E-101			
Q (Btu/hr)	2,340,000	Feed $\dot{m}$ (lbm/hr)	13,810
Feed T_{in} (°F)	140	Steam $\dot{m}$ (lbm/hr)	3,250
Feed T_{out} (°F)	410	Steam v (gpm)	300
Steam T_{in} (°F)	489	U_0 (Btu/hr-°F-ft^2)	130
Steam T_{out} (°F)	489	F	1
ΔT_{lm}	181.7	Number of shells	1
P_{Design} (psia)	170	A (ft^2)	91.4

Figure 22: Heater E-101 Design Summary

The Aspen Plus simulation specifies that a heat duty of 2.34 MM Btu/hr is required to heat the feed stream to the required temperature. This value was used in the preceding section to generate the mass flow rate of steam needed for the heat transfer. This value can be used with **Equation [5]** to estimate the size of the heater.

$$A = \frac{Q}{U_0 F \Delta T_{lm}} \quad [5]$$

Where: A = heat exchanger area, ft^2

Q = heat duty, Btu/hr

U_0 = overall heat transfer coefficient, Btu/hr-°F-ft^2

F = correction factor to account for the departure from true countercurrent flow

ΔT_{lm} = log mean temperature difference.

The overall heat transfer coefficient, U_0, has been estimated to be approximately 130 (Btu/hr-°F-ft^2). The design team made this decision based on heuristics given in Turton, et al [19]. Correction factor F is approximately 1.0 because the high pressure steam used for heat transfer is condensing inside the heat exchanger. The log mean temperature difference can be found using **Equation [6].**

$$\Delta T_{lm} = \frac{(Steam\ T_{in} - Feed\ T_{in}) - (Steam\ T_{out} - Steam\ T_{out})}{ln\left[\frac{(Steam\ T_{in} - Feed\ T_{in})}{(Steam\ T_{out} - Steam\ T_{out})}\right]} \quad [6]$$

The values for each temperature are located in **Figure 22.** Heater E-101 needs to have an area of 91 ft^2. This value will be used to estimate the capital and manufacturing costs found on **Page 75.** To avoid any shutdowns due to heater malfunction, we are requiring that a spare heater be purchased for this process. The design specification sheet for E-101 is found on **Page 36.**

Figure 23 is a design summary table for Cooler E-102.

Cooler E-102			
Q (Btu/hr)	4,080,000	Feed ṁ (lbm/hr)	10,250
Feed T_{in} (°F)	363	Water ṁ (lbm/hr)	310,739
Feed T_{out} (°F)	100	Water v (gpm)	688
Cooling Water T_{in} (°F)	87	U_0 (Btu/hr-°F-ft^2)	130
Cooling Water T_{out} (°F)	100	F	0.84
ΔT_{lm}	34.8	Number of shells	1
P_{Design} (psia)	64.7	A (ft^2)	1074

Figure 23: E-102 Design Summary

According to data obtained from the Aspen Plus simulation, 4.08 MM Btu/hr need to be removed from the combined vent stream in order to properly cool the wastewater to a temperature where it can be properly treated and disposed of. This is done by heating up cooling water to near 100 °F. **Equation [5]** can once again be used to estimate the heat transfer area required for E-102, where **Equation [6]** is once again used to determine the log mean temperature difference. The calculations used to determine the correction factor can be found in the appendix. However, it was found that the inlet and outlet temperatures of the cooling water and vent stream are great enough that the correction factor is approximately 1. The required estimated area for heat transfer is 1074 ft^2 for E-102. A spare cooler is required for design.

The design specification sheet for E-102 is found on **Page 37**, and a costing summary is found on **Page 76.**

Figure 24 is a design summary table for Air Cooler E-103.

Air Cooler E-103			
Q (Btu/hr)	2,260,000	Feed ṁ (lbm/hr)	3560
Feed T_{in} (°F)	518	Air ṁ (lbm/hr)	226,000
Feed T_{out} (°F)	140	Air v (gpm)	941
Cooling air T_{in} (°F)	70	U_0 (Btu/hr-°F-ft^2)	90
Cooling air T_{out} (°F)	110	F	1
ΔT_{lm}	155	A (ft^2)	162
P_{Design} (psia)	64.7		

Figure 24: E-103 Design Summary

The design team chose to use an air cooler because the nylon 6,6 will be in pellet form after exiting the extruder. E-103 relies on electricity to power the fan. According to the Aspen Plus simulation, 2.26 MM Btu/hr, or 662 kW of electricity, is required to cool the nylon 6,6 product stream. For this preliminary design, the design team estimated the ambient air temperature to 70°F, with the understanding that this can change on a day to day basis unless the air cooler is located indoors. The air outlet temperature and overall heat transfer coefficient were chosen based on design heuristics found in Turton, et al [19]. These values are 140 °F and 90 Btu/hr-°F-ft^2, respectively. The correction factor was estimated to be approximately 1 since air cooling is occurring in place of a conventional countercurrent heat exchanger. **Equation [5]** is once again used to calculate the heat transfer area of the cooler, with **Equation [6]** used to calculate the log mean temperature difference.

The design specification sheet for E-103 is found on **Page 38**, and a costing summary is found on **Page 76.**

Reactors:

Reactors R-101 and R-102 are used to convert the ADA, HMDA, and water feed to nylon 6,6. R-101 is a batch reactor that converts the reactants to nylon salt at a temperature of 518 °F and a pressure of 121 psia. R-102 then converts the nylon salt solution to nylon 6,6 by reducing the pressure to 8.33 psia, while maintaining the temperature of 518 °F. Carbon steel was chosen as the MOC due to its inexpensiveness and the lack of highly corrosive chemicals in the process. The reasons for using a batch reactor followed by a CSTR were explained in the previous Process Description section. **Figure 25** below is a design summary table for Reactor R-101.

Batch Reactor R-101			
T (°F)	518	N_{A0} (lbmol)	45.4
P_{Design} (psia)	17	N_A (lbmol)	0.012
$\dot{m}_{in}$ (lbm/hr)	13,810	Conversion	0.9997
Vent $\dot{m}_{out}$ (lbm/hr)	3,431	Q (Btu/hr)	726,000
Product $\dot{m}_{out}$ (lbm/hr)	10,379	Electricity Requirement (kW)	213
ρ_{Feed} (lbm/ft^3)	52.66	V (ft^3)	437.1
(hr)	1		

Figure 25: R-101 Design Summary

Reactor R-101 is a batch reactor that will be used to convert the feed into aqueous nylon salt. Because the reaction is slightly endothermic, this reactor will require a heated jacket in order to maintain the temperature of 518 °F. Polymerization has been shown to increase with temperature up to the point of thermal degradation. The design group chose 518 °F as the design temperature because it is the highest temperature observed in the literature that does not show signs of thermal degradation [23, 24]. Because this temperature is higher than that of high pressure steam, an electric heater will be needed to provide the heat. The design group chose to use a non-agitated heating jacket because we do not foresee any need for an agitated one. The energy balance was developed in the Aspen Plus simulation, and 726 M Btu/hr is needed to raise the feed to 518 °F, and be maintained throughout the reaction. This corresponds to an electricity requirement of 142 kW. **Equation [7]** is the batch reactor design equation, which is used to determine the volume of the reactor vessel needed for this reaction.

$$N_{A0}\frac{dX}{dt} = -r_A V \qquad [7]$$

Where: N_{A0} = initial amount of adipic acid in the reactor, lbmol
X = conversion
r_A = reaction rate, lbmol/ft^3-hr
V = reactor volume, ft^3

The reactor volume was calculated by using the batch reactor sizing techniques found in Turton, et al. The total reactor volume is found by **Equation [8].**

$$V = \frac{\dot{m}}{\rho}\left(\frac{5}{3}\right) \qquad [8]$$

Where: $\dot{m}$ = feed flow rate, lbm/hr,
ρ = density, lbm/ft

The 5/3 term is a multiplication value to account for the assumption that the reactor is 60% full while in operation. This value was found in Turton, et al. Using **Equation [8]** and the values for $\dot{m}$ and ρ in **Figure 25**, the estimated required volume for the Reactor R-101 can be calculated to be 437.1 ft^3. **Equation [9]** can be used to determine the reaction conversion in the batch reactor.

$$X = 1 = \frac{N_A}{N_{A0}} \qquad [9]$$

N_{A0}, the initial number of moles of adipic acid, is equal to 45.37 lbmol. According to the Aspen Plus simulation, the final number of moles of adipic acid in the stream, N_A, is 0.0123 lbmol. Thus the reaction conversion for Reactor R-101 is 0.9997.

Through a sensitivity analysis, it was determined that the optimum residence time for the reaction is approximately 1 hour. Leaving the reactants in the reactor for this amount of time results in the highest possible conversion of nylon salt. **Figure 26** is a graph of the molar concentrations vs time, showing that 1 hour is the optimum residence time for this reactor.

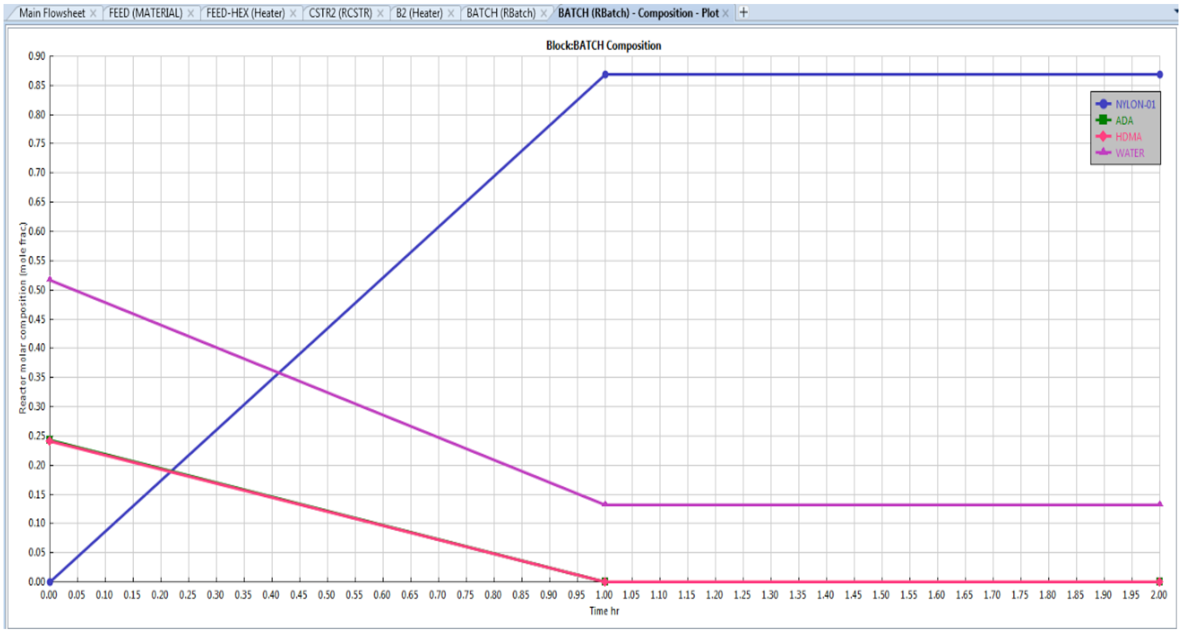


Figure 26: Molar Concentrations vs Time

Because the residence time is one hour, there will be at least one hour of dead time for the reactor. In order to maintain a smooth process, R-101 represents two identical reactors in parallel. While R-101 A is producing nylon salt, R-101 B will be filling up with reactants, and vice versa. This will allow for another batch of nylon salt to be produced while R-101 A is experiencing dead time. Thus the process of producing nylon 6,6 will be sped up, and there will not be a buildup of feed or reactants upstream. The design specification sheet for R-101 is found on **Page 39**, and a costing summary is found on **Page 75**. **Figure 27** is a design summary table for Reactor R-102.

R-102			
T (°F)	518	v_0 (ft^3/hr)	192.5
P_{Design} (psia)	58.33	(min)	3
$\dot{m}_{in}$ (lb/hr)	10,379	Conversion	1
Vent $\dot{m}_{in}$ (lb/hr)	129	Q (Btu/hr)	106,000
Product $\dot{m}_{in}$ (lb/hr)	10,250	Electricity Requirement (kW)	31
F_{A0} (lbmol/hr)	45.3	V (ft^3)	548.6
ρ (lb/ft^3)	52.66		

Figure 27: R-102 Design Summary

Reactor R-102 is a continuously stirred tank reactor (CSTR) that is used to convert the nylon salt stream from R-101 into nylon 6,6. The reactor does this by lowering the pressure to 8.33 psia and venting out what water remains in the process. The pressure was chosen as it was the ideal pressure found in the literature. This results in the nylon molecules attaching to each other and forming nylon 6,6. Like R-101, R-102 will require a heated jacket to maintain a constant temperature of 518 °F. The temperature on R-102 was selected for the same reasons as R-101. An electric heater and a not-agitating jacket were chosen for similar reasons as those for R-101. According to the Aspen Plus simulation, 71 M Btu/hr are required to maintain the reactor temperature at a constant 518 °F, corresponding to an electricity requirement of 21 kW.

The CSTR design equation is shown in **Equation 10** below.

$$V = \frac{F_{A0}X}{-r_A} \qquad [10]$$

Where: V = volume, ft^3,

F_{A0} = flowrate of nylon salt feed, lbmol/hr

X = conversion from nylon salt to nylon 6,6

r_A = reaction rate, lbmol/ft^3-hr

The conversion is assumed to be 1 because all of the nylon salt (excluding water) is being converted to nylon 6,6. The reaction rate is explained fully in the Process Description section. The value for F_{A0} is found in **Figure 27**, and is equal to 45.3 lbmol/hr.

The reactor volume was calculated by using **Equation 11** below:

$$V = \tau v_o \qquad [11]$$

Where: τ = residence time (minutes)

v_0 = initial volumetric flow rate (192.5 ft^3/hr)

The residence time for R-102 was determined to be 0.05 hours, or 3 minutes. A sensitivity analysis for the degree of polymerization was completed to determine this value. **Figure 28** shows the sensitivity analysis. The residence time chosen is not quite at the peak of the graph. This was done because the reactor volume drastically alters the capital costs of the reactor. The design group chose a residence time of 0.05 hours because this value results in the lowest capital cost while remaining a marginal difference in the optimum degree of polymerization.
From **Equation 11**, the volume of R-102 is 577.5 ft^3.

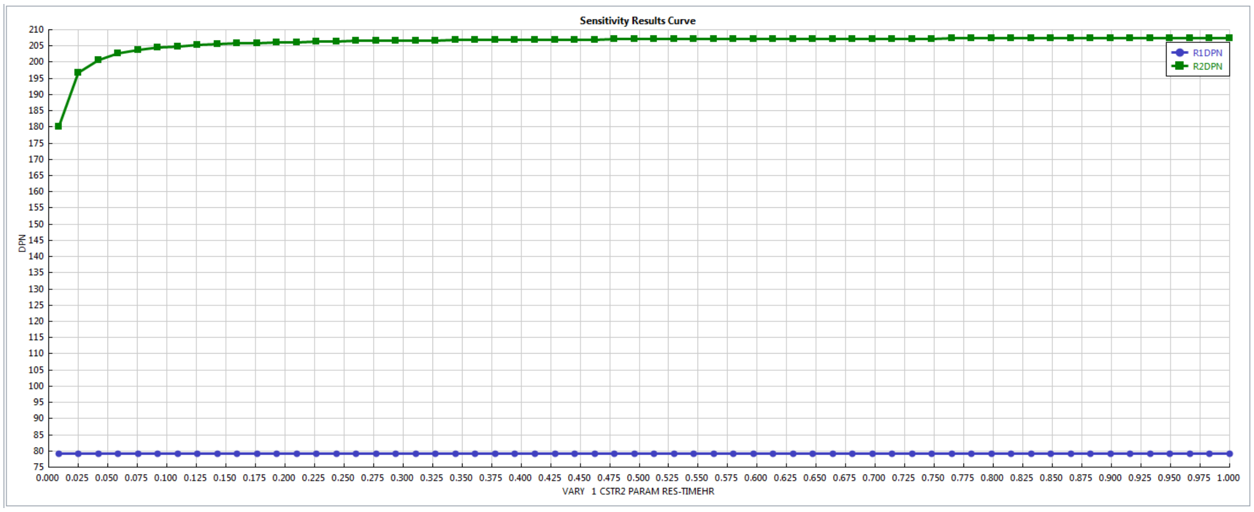


Figure 28: R-102 Residence Time Sensitivity Analysis

R-102 will contain a spare reactor vessel in order to avoid complete shutdown due to any equipment malfunctions. The design specification sheet for R-102 is found on **Page 40**, and a costing summary is found on **Page 75**.

Process Vessels:

Figure 29 is a design summary for Process Vessel V-101.

V-101			
T (°F)	518	v_0 (ft^3/hr)	192.5
P_{Design} (psia)	171	V (ft^3)	64
ṁ (lbm/hr)	10,379	L/D	3
ρ (lbm/ft^3)	52.66	L (ft)	9
Holdup time (min)	10	D (ft)	3
L/D	3		

Figure 29: V-101 Design Summary

The design team made the decision to add a process vessel after Reactor R-101. Vessel V-101 will act as a holding tank for the nylon salt solution before it continues on in the process. Vessel V-101 will provide time to identify any issues with the nylon salt solution, and also provide a way to drain the process should the reaction taking place in R-101 fail for any reason, or produce an impure product. Placing this vessel before R-102 will save the company utility costs associated with R-102 should the first reaction fail.

Following the design heuristics in Turton, et al [19], the ideal length to volume ratio is 3, the average holdup time should be approximately 10 minutes, and the vessel should be assumed to be 50% full at all times. Therefore, **Equation 12** can be used to determine the vessel volume.

$$V = 2\dot{m}t_{holdup} \qquad [12]$$

Here, ṁ is the volumetric flow rate into V-101, and is equal to 192.5 ft^3/hr. Thus, the volume required for V-101 is equal to 64 ft^3. Assuming that V-101 is a horizontal cylinder and using an L/D of 3, vessel length is calculated to be 9 ft and the vessel diameter to be 3ft.

Vessel V-101 will be made of carbon steel due to its low cost. The design specification sheet for V-101 is found on **Page 41**, and a costing summary is found on **Page 75**.

Extruder:

An extruder, X-101, is required near the end of the process to produce the nylon 6,6 pellets that will be sold. The design team investigated different extruders, and finally decided on the plastic extruder machine manufactured by Longshi (Dongguan) Machinery Plastic Company, Ltd located in Shenzhen, China [25]. This particular extrusion unit is made of nitrided steel and has dimensions of 11ft x 5.9ft x 5.2 ft. It is computerized and thus produces the nylon 6,6 pellets automatically. The model number is NR-II-46-001. Two extruder units will be purchased so that a spare will be present on site. The design specification sheet for X-101 is found on **Page 42**, and a costing summary is found on **Page 75.**

Equipment Specification Sheets: Table of Contents

The following eight pages consist of equipment specification sheets for the process equipment used in this design. **Figure 30** below is a table of contents for the equipment specification sheets.

Figure 30: Equipment Specification Sheets Table of Contents

Pump

Identification:	**Item**	Pump	Date: 9 March 2017
	Item No.	P-101	
	No. required	2	By: DC, RD, RK, and DM

Function: Increase the pressure of the Adipic Acid, HMDA, and Water feed.

Operation: Pump

Materials Handled:	Stream In	Stream Out			
Quantity (lb/hr):	13,810	13,810			
Composition:					
Adipic Acid	0.480	0.480			
HMDA	0.382	0.382			
Water	0.138	0.138			
Temperature (°F):	140	141			
Operating Pressure (psia):	14.7	120			

Design Data:	Fluid Power: 1.71 hp	Pump efficiency used: 0.350
	Brake Power: 4.88 hp	Net work required: 4.88 hp
	Electricity: 3.6 kW	Outlet pressure: 120 psia
	Volumetric Flowrate: 223.21 ft^3/hr	Design Pressure: 170 psia
	Pressure change: 105.3 psi	Motor Size: 10 hp
	NPSH available: 30.54 ft-lbf/lb	Type: Centrifugal
	Head developed: 245.1 ft-lbf/lb	MOC: CS

Utilities: Electricity at 3.6 kW

Controls: Flow control valve located downstream

Comments:

Heat Exchanger

Identification: Item	Heat Exchanger		Date: 9 March 2017
Item No.	E-101		
No. required	2		By: DC, RD, RK, and DM

Function: Increase the temperature of the Adipic Acid, HMDA, and Water feed.

Operation: Continuous

Materials Handled:	Stream In	Stream Out	Steam in	Steam Out
Quantity (lb/hr):	13,810	13,810	3,250	3,250
Composition:				
Adipic Acid	0.480	0.480	0	0
HMDA	0.382	0.382	0	0
Water	0.138	0.138	1	1
Temperature (°F):	141	410	489	489
Operating Pressure (psia):	120	117.57	614.7	614.7

Design Data: Outlet Temperature: 410 °F — MOC: CS Shell/SS Tubes

Outlet Pressure: 117.57 psia

Design Pressure: 170 psia

Vapor Fraction: 0

Heat duty: 2,340,000 Btu/hr

Area: 91.4 ft^2

Type: Shell and Tube

Configuration: Counter current

Utilities: High Pressure Steam (600psig) at 3250 lb/hr

Controls: Temperature control system. Flow valve located on steam line

Comments:

Heat Exchanger

Identification:	Item	Heat Exchanger	Date: 9 March 2017
	Item No.	E-102	
	No. required	2	By: DC, RD, RK, and DM

Function: Decrease the temperature of the vent water for wastewater disposal

Operation: Continuous

Materials Handled:	Stream In	Stream Out	Cooling Water In	Cooling Water Out
Quantity (lb/hr):	3,560	3,560	310,739	310,739
Composition:				
Adipic Acid	Trace	Trace	0	0
HMDA	0.011	0.011	0	0
Water	0.989	0.989	1	1
Temperature (°F):	363	100	87	100
Operating Pressure (Psia):	8.33	14.7	14.7	14.7

Design Data:
Outlet Temperature: 100 °F
Outlet Pressure: 14.7 psia
Design Pressure: 64.7 psia
Vapor Fraction: 0
Heat duty: -4,080,000 Btu/hr
Area: 1074 ft^2
Type: Shell and Tube

Configuration: Countercurrent
MOC: CS Shell/SSTubes

Utilities: Cooling Water (87°F) at 310,739 lb/hr

Controls: Temperature control system. Flow valve located on cooling water line.

Comments:

Air Cooler

Identification:	Item	Air Cooler	Date: 9 March 2017
	Item No.	E-103	
	No. required	2	By: DC, RD, RK, and DM

Function: Cool the Nylon 6,6 pellets

Operation: Continuous

Materials Handled:	Stream In	Stream Out	Air Stream In	Air Stream Out
Quantity (lb/hr):	10,250	10,250	226,000	226,000
Composition:				
Adipic Acid	Trace	Trace	0	0
HMDA	Trace	Trace	0	0
Water	0.0007	0.0007	0	
Nylon 6,6	0.9993	0.9993	0	0
Air	0	0	1	1
Temperature (°F):	518	140	70	110
Operating Pressure (Psia):	8.33	14.7	14.7	14.7

Design Data: Heat Duty: -2,260,000 Btu/hr

Design Pressure: 64.7 psia

MOC: Carbon Steel

Area: 162 ft^2

Type: Electric Fan

Utilities: Electricity at 662 kW

Controls: None

Comments:

Reactor Vessel

Identification:	Item	Batch Reactor	Date: 9 March 2017
	Item No.	R-101	
	No. required	3	By: DC, RD, RK, and DM

Function: Allow for the reaction and production of Nylon 6,6

Operation: Batch-Jacketed

Materials Handled:	Stream In	Product Stream	Vent Stream		
Quantity (lb/hr):	13,810	10,379	3,431		
Composition:					
Adipic Acid	0.480	Trace	Trace		
HMDA	0.382	Trace	0.012		
Water	0.138	0.012	0.988		
Nylon 6,6	0	0.988	0		
Temperature (°F):	410	518	374		
Pressure (Psia):	118	121	121		

Design Data: Operating Temperature: 518°F

Operating Pressure: 121 psia

Design Pressure: 171 psia

Heat duty per cycle: 726,355 Btu/hr

Residence Time: 1 hour

MOC: Carbon Steel

Volume: 437 ft^3

Utilities: Electricity at 213 kW

Controls: Pressure Control Valve located downstream. Temperature control system located on heating jacket.

Comments: Jacketed reactor vessel with an electric heater providing the energy. Non-agitating.

Reactor Vessel

Identification: Item	CSTR		Date: 9 March 2017
Item No.	R-102		
No. required	2		By: DC, RD,RK, and DM

Function: Allow for the Step-Growth reaction increase the molecular weight of Nylon 6,6

Operation: Continuous-Jacketed

Materials Handled:	Stream In	Product Stream	Vent Stream		
Quantity (lb/hr):	10,379	10,250	129		
Composition:					
Adipic Acid	Trace	Trace	Trace		
HMDA	Trace	Trace	Trace		
Water	0.012	0.0007	1		
Nylon 6,6	0.988	0.9993	0		
Temperature (°F):	518	518	518		
Operating Pressure (psia):	121	8.33	8.33		

Design Data: Operating Temperature: 518°F

Operating Pressure: 8.33 psia

Design Pressure: 58.33 psia

Heat duty per cycle: 105933 Btu/hr

Residence Time: 3 minutes

MOC: Carbon Steel

Volume: 577.5 ft^3

Utilities: Electricity at 31 kW

Controls: Pressure and Level control valves located downstream. Temperature control system in heating jacket.

Comments: Jacketed reactor vessel with an electric heater providing the energy. Non-agitating.

Product Receiver Vessel

Identification:	Item	Process Vessel	Date: 9 March 2017
	Item No.	V-101	
	No. required	2	By: DC, RD, RK, and DM

Function: Maintain R-101 Level

Operation: Continuous

Materials Handled:	Stream In	Product Stream			
Quantity (lb/hr):	10,379	10,379			
Composition:					
Adipic Acid	Trace	Trace			
HMDA	Trace	Trace			
Water	0.012	0.012			
Nylon 6,6	0.988	0.988			
Temperature (°F):	518	518			
Operating Pressure (psia):	121	121			

Design Data: Operating Temperature: 518°F

Operating Pressure: 121 psia

Design Pressure: 171 psia

MOC: Carbon Steel

Volume: 64 ft^3

Utilities: None

Controls: Level control valve located downstream.

Comments:

Extruder

Identification: Item	Extruder		Date: 9 March 2017
Item No.	X-101		
No. required	2		By: DC, RD, RK, and DM

Function: Create Nylon 6,6 pellets

Operation: Continuous

Materials Handled:	Stream In	Stream Out			
Quantity (lb/hr):	10,250	10,250			
Composition:					
Adipic Acid	Trace	Trace			
HMDA	Trace	Trace			
Water	0.0007	0.0007			
Nylon 6,6	0.9993	0.9993			
Temperature (°F):	518	518			
Operating Pressure (Psia):	8.33	8.33			

Design Data: Type: Pellet Extruder — Screw Type: Segment

Model: NR-II-46 Twin Screw Extruder — L/D: 40

MOC: Nitrided Steel

Size: 11ft x 5.9ft x 5.2ft

Motor: 55 kW

Power: AC380, 50Hz, 3 phase

Screw Diameter: 1.8 in `

Utilities: Electricity at 55 kW

Controls: 11 zone PID temperature controllers

Comments: Manufactured by Longshi (Dongguan) Machinery Plastuc Co., Ltd. Shenshen, China.

Capital Cost Summary

The cost for each piece of equipment was estimated by using the module costing technique in Turton, et al [19]. In this approach, costs are first calculated for base conditions and then adjusted based on the equipment type, system pressure, and materials of construction in a specific design. Base conditions are assumed to be equipment made of carbon steel and operating at near-ambient pressures. The bare module cost for a given piece of equipment can be calculated by using **Equation 13,** shown below.

$$C_{BM} = C_p^o\left[B_1 + B_2 F_p F_M\right] \qquad [13]$$

Where: C_{BM} = bare module equipment cost, $

C_p^o = purchased cost in base conditions, $

B_1 = equipment type factor

B_2 = equipment type factor

F_p = pressure factor

F_M = material of construction factor

For heat exchangers, F_p is calculated as shown below in **Equation 14**.

$$log_{10}F_p = C_1 + C_2 log_{10}P + C_3(log_{10}P)^2 \qquad [14]$$

Where: C_i = pressure factor

P = pressure, barg

For process vessels, F_p can be calculated using **Equation 15**. Unless otherwise specified, CA is assumed to be 0.00315 m and t_{min} is assumed to be 0.0063 m.

$$F_p = \frac{\frac{(P+1)D}{(2)(944)(0.9)-1.2(P+1)}+CA}{t_{min}} \qquad [15]$$

Where: P = pressure, barg

D = diameter, m

CA = corrosion allowance, m

t_{min} = minimum allowable vessel thickness, m

The costs calculated using the above equations can then be adjusted to account for inflation by using the Chemical Engineering Plant Cost Index (CEPCI) by using **Equation 16**.

$$C_2 = C_1 \left(\frac{I_2}{I_1}\right) \quad [16]$$

Where: C_i = purchased cost, $

I_i = cost index

The purchased costs and bare module costs for each piece of equipment for both the Batch/CSTR and PFR/CSTR options are shown in **Figures 31** and **32**, respectively.

Batch/CSTR Equipment Costs		
	$C_{p,2016}$	$C_{BM,2016}$
P-101	$ 6,200	$ 16,000
E-101	$ 38,000	$ 96,000
R-101	$ 66,000	$ 265,000
V-101	$ 8,800	$ 23,500
R-102	$ 76,500	$ 306,000
E-102	$ 54,000	$ 138,000
E-103	$ 32,500	$ 106,000

Figure 31: Batch/CSTR Capital Costs

PFR/CSTR Equipment Costs		
	$C_{p,2016}$	$C_{BM,2016}$
P-101	$ 6,200	$ 16,000
E-101	$ 38,000	$ 96,000
R-101	$ 75,000	$ 290,000
V-101	$ 8,800	$ 23,000
R-102	$ 77,000	$ 310,000
E-102	$ 50,000	$ 130,000
E-103	$ 35,000	$ 115,000

Figure 32: PFR/CSTR Capital Costs

Because there were no available costing correlations for an extruder, the group requested a quote for an industrial extruder and pelletizer. An average price of $26,500 [25] was used for calculations in this project.

Once the bare module cost has been determined, the total module cost can be calculated. This cost accounts for making small changes to an existing facility by adding contingency costs and fees to the bare module cost. For this project, the grassroots cost was also calculated. The grassroots cost includes costs for site development and auxiliary buildings, which are assumed to be 50% of the total bare module cost. The total module cost is calculated by using **Equation 17**, and the calculation for the grassroots cost is shown in **Equation 18**.

$$C_{TM} = \sum_{i=1}^{n} C_{TM,i} = 1.18 \sum_{i=1}^{n} C_{BM,i} \qquad [17]$$

$$C_{GR} = C_{TM} + 0.50 \sum_{i=1}^{n} C_{BM,i}^{o} \qquad [18]$$

Working capital was approximated as 15% of the fixed capital costs, according to Turton et al [19]. The total capital investment can be calculated using **Equation 19**, shown below.

$$Total\ Capital\ Investment = Fixed\ Capital + Working\ Capital \qquad [19]$$

Figure 33 shows a summary of all capital costs.

Capital Costs		
	Batch/CSTR	**PFR/CSTR**
Fixed Capital (Grassroots)	$ 3,400,000	$ 4,000,000
Working Capital	$ 510,000	$ 600,000
Total Capital Investment	$ 4,025,000	$ 4,600,000

Figure 33: Summary of Capital Costs

Safety, Health, and Environmental Considerations:

Throughout the development of this process plant, safety was kept at the forefront of all decisions. The first step to ensuring each step of the process was as safe as possible was an initial hazard analysis on the raw materials being used for this process. **Figure 34** below displays an initial raw material hazard analysis.

Material Properties	Hazard
Health	
Nylon 6,6	Fine particulates may lead to eye or lung irritation upon exposure. In addition, thermal decomposition may lead to the release of toxic or irritating vapors.
Adipic acid	Skin and eye irritant; hazardous in case of ingestion and inhalation. Repeat exposure can cause organ damage.
HMDA	Substance is toxic to blood, kidneys, lungs, and liver. Very hazardous in case of skin contact, eye contact, and inhalation. Inhalation of dust can lead to irritation of gastrointestinal and respiratory tracts.
Flammability	
Adipic acid	Slightly flammable to flammable at high temperatures
HMDA	Slightly flammable to flammable at high temperatures

Figure 34: Hazard Identification Summary [26-28]

Both adipic acid and HMDA have been found to be slightly flammable at elevated temperatures. Therefore, research was done into the probability of the raw materials catching fire, as well as any release limits set by the EPA. This research led to the conclusion that so long as the raw materials were not exposed to excessively high temperatures or open flame, the probability of fire was very low. In order to further mitigate flammability risks, the raw materials used were diluted with water so as to reduce the potential for combustion. **Figures 35 and 36** below display the results of this flammability analysis.

	OSHA (PSM)	EPA (RMP)	
Component	**PEL (ppm)**	**Threshold Level (lbs)**	**Known Hazards**
Water	N/A	N/A	N/A
Nylon 6,6	N/A	N/A	N/A
Adipic acid	N/A	N/A	Flammable, Health Hazard
HMDA	N/A	N/A	Flammable, Health Hazard

Figure 35: Threshold Level Analysis

NFPA Ratings				
Component	**Health**	**Flammability**	**Instability**	**Special**
Water	0	0	0	N/A
Nylon 6,6	0	0	0	N/A
Adipic acid	2	1	0	N/A
HMDA	3	2	0	N/A

Figure 36: NFPA and Flammability Analysis

In order to avoid the release of any raw materials or product to the environment, all vent streams were set through wastewater treatment before being released. This necessary step ensures that any water released from this plant will not pose a negative impact to the environment or the surrounding Calvert City area.

After investigating the hazards associated with the raw materials themselves, an investigation into process hazards was also performed. This analysis used the identified hazards and determined ways to mitigate these hazards using inherently safe principles of design. These actions were turned into designed components of this process. **Figure 37** below displays the results of this inherent safety analysis.

Hazard	Inherent Safety Concept	Action
Nylon 6,6 Health Hazard	Minimization	Send newly-produced pellets directly to packaging to avoid development of irritating dust or degradation
ADA Health Hazard	Moderation	Raw material diluted with water to reduce irritation hazard
HMDA Health Hazard	Moderation	Raw material diluted with water to reduce irritation hazard
ADA Flammability Hazard	Moderation	Raw material diluted with water to reduce flammability
HMDA Flammability Hazard	Moderation	Raw material diluted with water to reduce flammability
High-Temperature Heating Fluid Thermal Hazard	Substitution	Use electric heaters in place of other dangerous heating fluids

Figure 37: Inherent Safety Analysis

Additional measures were put in place in order to enhance the safety of the process design. For instance, in choosing reactors for this process, the choice was made to use multiple reactors with lower volume as opposed to a larger single reactor. This aided in creating a more inherently safe design, as a lower volume of material would be reacting at once. In the event of an incident, less material will be released, thus causing less damage or harm to workers.

When designing heated jackets for the reactors themselves, the decision was made to use electric heaters as opposed to utilizing a high-heat capacity heating media. This allowed for high levels of heating without the danger that accompanies such a media, thus eliminating another potential hazard.

For the design of shell-and-tube heat exchangers E-101 and E-102, stainless steel was chosen as the material of construction in order to avoid corrosion and the potential combination of water/steam with process material. If the process materials were to come in contact with the high pressure steam of E-101, the feed would become contaminated, and could potentially lead to thermal degradation. This breach would cause a safety problem, as well as lead to poor-quality nylon product.

All process equipment was designed for 50 psi above operating pressure so as to provide a safety cushion in the event of elevated temperatures or pressures inside the equipment. In addition, all vent streams were cooled to 100 °F before being sent to wastewater treatment in order to avoid the release of high-energy heated water or steam. In the event of an accidental release of the vent stream, the lowered temperature will prevent potential burns or injury that could result from a high-energy heated water stream. In a similar manner, the freshly extruded nylon pellets at the end of the process are immediately cooled in order to ensure they are safe to handle.

A process vessel was added in between R-101 and R-102 in order to provide greater control over the process and to serve as a safety measure. This process could have been designed to have aqueous nylon flow directly from R-101 and R-102, but this choice could have posed problems in the event of any disruption to the process. The current design's inclusion of vessel V-101 allows operators to drain R-101 and stop the process if any part of the process is malfunctioning. In the case of an incident, the addition of a holding tank in between reactors helps to reduce the consequences of a malfunction.

Safety also played a role in the ultimate decision of reactor scheme. As previously mentioned, PFR/CSTR and CSTR/CSTR reactor schemes were also investigated in addition to the final Batch/CSTR scheme. The design group ultimately decided on the Batch/CSTR scheme because of its simplicity and safety. Batch reactors are inherently simpler than plug-flow reactors, and thus the group decided that ensuring the safety of such a reactor would be easier. The Batch/CSTR scheme also yielded a more profitable process, but only marginally more so than the PFR/CSTR scheme. Therefore, the added simplicity and safety of the Batch/CSTR process was the deciding factor in choosing a final design.

As previously mentioned, safety was considered in all steps of the process design of this process. In addition to the previously mentioned analyses and considerations, a HAZOP analysis was performed to investigate the future steps needed to ensure the safety and hazard mitigation of the process in future design steps. The results of this analysis can be found on the following pages. **Figure 37** below details the various parts of the HAZOP analysis and where to find them on subsequent pages.

Equipment Label	Equipment Name	HAZOP Table Location
VLV 101 A/B	Feed Mixing Valve	Pg. 49
P-101 A/B	Feed Pump	Pg. 50
E-101 A/B	Feed Preheater	Pgs. 51-52
R-101 A/B/C	Pressurized Jacketed Batch Reactor	Pg.53
V-101 A/B	Safety Storage Vessel	Pg. 54
R-102 A/B	Near-Vacuum Jacketed CSTR	Pg. 55
E-102 A/B	Vent Condenser	Pg. 56
VLV-102 A/B	Vent Stream Mixing Valve	Pg. 57
E-103 A/B	Air Cooler	Pg. 58
X-101 A/B	Nylon Pellet Extruder	Pg. 59

Figure 38: HAZOP Analysis Table of Contents

PROCESS UNIT: VLV-101 A/B, FEED MIXING VALVE, FIGURE 3

INTENTION: MIX RAW MATERIAL STREAMS 1 & 2				
GUIDE WORD:	**Deviation**	**Cause**	**Consequence**	**Action**
NO	No Stream 1 flowrate	Blockage or lack of adipic acid	Build-up of HDMA in R-101; No reaction	Consider an interlock on ADA Flow
	No Stream 2 flowrate	Blockage or lack of HMDA	Build-up of ADA in R-101; No reaction	Consider an interlock on HMDA Flow
MORE OF	Stream 1 flowrate	Surge of ADA	Unstable operation	Alarm to notify of surge
	Stream 2 flowrate	Surge of HMDA	Unstable operation	Alarm to notify of surge
	Temperature	Sudden/unexpected reaction in Stream 3	Reduction in Stream 4 flowrate; two-phase flow in pump	Consider interlock on flow
	Pressure	Downstream blockage	Tube failure	Pressure-relief system on tubes
LESS OF	Temperature	Ambient conditions	Reactants are not high enough temperature for reaction to occur	Control system to raise steam rate and therefore temperature
	Less flow in Stream 1 than in Stream 2	Blockage in Stream 1	Unbalanced reaction; lowered conversion.	Keep regular supply of ADA
	Less flow in Stream 2 than in Stream 1	Blockage in Stream 2	Unbalanced reaction; lowered conversion.	Keep regular supply of HMDA
AS WELL AS	Air in Stream 1	Pipe leak	Pump cavitation	Maintain supply of ADA
	Air in Stream 2	Pipe leak	Pump cavitation	Maintain supply of HMDA
REVERSE	Reversal of Stream 1	No probable cause		
	Reversal of Stream 2	No probable cause		
OTHER THAN	Impurities in Stream 1	Impurities in feed	None at this point of process	
	Impurities in Stream 2	Impurities in feed	None at this point of process	
	Stream 1 replaced by other acid	Wrong connection by sabotage	Loss of product possible	Redundant management controls on storage facilities. Level control downstream
	Stream 2 replaced by other acid	Wrong connection by sabotage	Loss of product possible	Redundant management controls on storage facilities. Level control downstream

PROCESS UNIT: P-101 A/B, FEED PUMP, FIGURE 3

INTENTION: INCREASE PRESSURE OF FEED STREAM				
GUIDE WORD:	**Deviation**	**Cause**	**Consequence**	**Action**
NO	Stream 3 flow	Blockage in line	No product, possibly cavitation	Shutdown pump; interlock on Stream 3
	No ADA in Stream 3	Blockage or lack of ADA	Build-up of HDMA in R-101; No reaction	Consider an interlock on ADA Flow
	NO HMDA in Stream 3	Blockage or lack of HMDA	Build-up of ADA in R-101; No reaction	Consider an interlock on HMDA Flow
MORE OF	ADA in Stream 3	Surge of ADA	Unstable operation	Alarm to notify of surge
	HMDA in Stream 3	Surge of HMDA	Unstable operation	Alarm to notify of surge
	High Temperature	Ambient conditions	Vaporization; pump cavitation	Pump shutdown; cool down feed
	High Pressure	Blockage in upstream flow	Pump cavitation	Pump shutdown; consider pressure relief valve prior to pump
LESS OF	ADA in Stream 3	Surge of HMDA	Unstable operation; loss of cash flow	Alarm to notify of surge
	HMDA in Stream 3	Surge of ADA	Unstable operation; loss of cash flow	Alarm to notify of surge
	Low Temperature	Ambient conditions	Need higher heat duty downstream	Increase Steam Flowrate
AS WELL AS	Additional water in Stream 3	Water leak from other process	Diluted raw materials fed to R-101	None - avoid water leaks
PART OF	Low ADA in Stream 3	Blockage or lack of adipic acid	Build-up of HDMA in R-101; No reaction	Consider an interlock on ADA Flow
	Low HMDA in Stream 3	Blockage or lack of HMDA	Build-up of ADA in R-101; No reaction	Consider an interlock on HMDA Flow
OTHER THAN	Impurities in Stream 3	Impurities in feed	None at this point of process	None

PROCESS UNIT: E-101 A/B, FEED PREHEATER, FIGURE 3

INTENTION: HEAT FEED STREAM TO 410 °F

GUIDE WORD:	Deviation	Cause	Consequence	Action
NO	Stream 4 flowrate	Line blockage	No further process	Clear line
	Steam flowrate	Line blockage	Cold process, low conversion	Temperature controller on Stream 5; clear line
MORE OF	Stream 4 flowrate	Excess materials; valve or pump malfunctions	Poor heat exchange; low conversion	Temperature controller; increase steam flowrat
	Stream flowrate	Temperature controller malfunction	Increased stream 5 temperature; degradation; overheating; over-pressurization; explosion	Cut steam flowrate off; replace temperature controller
	Stream 4 temperature	Ambient conditions; Flowrate controller malfunction	Increased stream 5 temperature; degradation; overheating; over-pressurization; explosion	Temperature controller; reduce steam flowrate
	Stream 4 pressure	Ambient conditions; Flowrate controller malfunction	Increased stream 5 temperature; degradation; overheating; over-pressurization; explosion	Temperature controller; reduce steam flowrate; pressure relief valve
LESS OF	Stream 4 flowrate	Line blockage	Increase heat transfer; increased Stream 5 temperature; overheating; over-pressurization; explosion	Control valve to reduce steam flowrate
	Steam flowrate	Temperature controller malfunction; line blockage	Less heat transfer; reduced conversion	Replace temperature controller to increase steam flowrate; clear blockage
	Stream 4 temperature	Ambient conditions; Flowrate controller malfunction	Less heat transfer; reduced conversion	Replace temperature controller to increase steam flowrate; clear blockage
	Stream 4 pressure	Ambient conditions; Flowrate controller malfunction	Less heat transfer; reduced conversion	Replace temperature controller to increase steam flowrate; clear blockage
AS WELL AS	Steam or water in line	Steam line leak	Incorrect heat transfer; increased temperature; possible degradation	Cut steam line; repair leak
PART OF	Low ADA in Stream 4	Blockage or lack of ADA	Build-up of HDMA in P-101; No reaction	Consider an interlock on ADA Flow
	Low HMDA in Stream 4	Blockage or lack of HMDA	Build-up of ADA in P-101; No reaction	Consider an interlock on HMDA Flow
REVERSE	Reversal of flow from Stream 4 into Stream 3	No probable cause		

OTHER THAN	Impurities in Stream 4	Impurities in Feed	None at this point of process

PROCESS UNIT: R-101 A/B/C, PRESSURIZED JACKETED BATCH REACTOR, FIGURE 3

INTENTION: REACT RAW MATERIALS TO FORM NYLON SALT

GUIDE WORD:	Deviation	Cause	Consequence	Action
NO	Stream 5 flowrate	Blockage	No reaction	Unblock
MORE OF	Stream 5 flowrate	Upstream instrument malfunction	Over-pressurization; decreased temperature	Pressure control to release vapor; increase hea duty across jacket
	Temperature	Ambient conditions; heat exchanger malfunction	Degradation, over-pressurization	Pressure controller to release vapor; temperature controller to decrease heat duty across jacket
	Pressure	Ambient conditions; heat exchanger malfunction	Degradation; over-pressurization	Pressure control to release vapor; temperature controller to decrease heat duty across jacket
LESS OF	Stream 5 flowrate	Upstream instrument malfunction	Under-pressurization; increased temperature	Decrease heat duty across jacket
	Temperature	Ambient conditions; heat exchanger malfunction	Increased heat exchange, increased reactor temperature; increased pressure	Pressure controller to release water vapor; increase heat duty across jacket
	Pressure	Ambient conditions; heat exchanger malfunction	Lowered temperature; lowered conversion	Temperature controller to increase heat duty across jacket
AS WELL AS	Steam or water in line	Steam line leak	Incorrect heat transfer; increased temperature; possible degradation	Cut steam line; repair leak
PART OF	Low ADA in Stream 5	Blockage or lack of ADA	Build-up of HDMA in P-101; no reaction	Consider an interlock on ADA Flow
	Low HMDA in Stream 5	Blockage or lack of HMDA	Build-up of ADA in P-101; no reaction	Consider an interlock on HMDA Flow
REVERSE	Reversal of flow from Stream 4 into Stream 3	No probable cause		
OTHER THAN	Impurities in Stream 5	Impurities in feed	None at this point of process	

PROCESS UNIT: V-101 A/B, SAFETY STORAGE VESSEL, FIGURE 3

INTENTION: HOLD NYLON SALT BEFORE BEING SENT TO R-102

GUIDE WORD:	Deviation	Cause	Consequence	Action
NO	Stream 7	Upstream Blockage	No process	Unblock
MORE OF	Stream 7	Pump malfunction; increased pressure	Possible vessel overflow	Open level control valve on Stream 8
	Pressure	Pump malfunction; downstream blockage; level control malfunction	Possible vessel overflow	Shut VLV-102 to shutdown process; unblock downstream
	Temperature	Pump malfunction, increased pressure	Possible vessel overflow	Shut VLV-102 to shutdown process; unblock downstream
LESS OF	Stream 7	Upstream blockage; low pressure	Less product; downstream pressure upset	Level control
	Pressure	Upstream blockage; low pressure	Less product; downstream pressure upset	Level control
	Temperature	Upstream blockage; low pressure	Less product; downstream pressure upset	Level control
AS WELL AS	Steam or water in line	No probable cause		
PART OF	Low nylon in Stream 7	Low conversion in R-101	Less product	
REVERSE	Reversal of flow from Stream 8 into Stream 7	No probable cause		
OTHER THAN	Impurities in Stream 7	Impurities in feed	None at this point of process	

PROCESS UNIT: R-102 A/B, NEAR-VACUUM JACKETED CSTR, FIGURE 3

INTENTION: REMOVE WATER FROM NYLON SALT TO YIELD FINAL NYLON 6,6 PRODUCT

GUIDE WORD:	Deviation	Cause	Consequence	Action
NO	Stream 8 flowrate	Blockage	No reaction	Unblock
	Steam flowrate	Blockage; temperature controller malfunction	Reduced temperature; lowered conversion	Replace temperature controller; increase steam flowrate
MORE OF	Stream 8 flowrate	Upstream instrument malfunction	Over-pressurization; decreased temperature	Pressure controller to release vapor; increase steam flowrate to jacket
	Stream 8 Temperature	Ambient conditions; heat exchanger malfunction	Degradation; over-pressurization	Pressure controller tor release vapor; Temperature controller to decrease heat input
	Stream 8 Pressure	Ambient conditions; heat exchanger malfunction	Degradation; over-pressurization	Pressure controller to release vapor; temperature controller to decrease heat input
LESS OF	Stream 8 flowrate	Upstream instrument malfunction	Under-pressurization; increased temperature	Decrease steam flowrate to jacket
	Temperature	Ambient conditions; heat exchanger malfunction	Increased heat exchange; increased reactor temperature; increased pressure	Pressure controller to release water vapor; increase steam flowrate
	Pressure	Ambient conditions; heat exchanger malfunction	Lower temperature; lowered conversion	Temperature controller to increase steam flowrate
AS WELL AS	Steam or water in line	Stream 9 leak	Incorrect heat transfer; increased temperature; possible degradation	Repair leak
PART OF	Low Nylon	No probable cause		
REVERSE	Reversal of flow from Stream 9 into Stream 8	No probable cause		
	Reversal of flow from Stream 8 into Stream 9	No probable cause		
OTHER THAN	Impurities in Stream 8	Impurities in feed	None at this point of process	

PROCESS UNIT: E-102 A/B, VENT CONDENSOR, FIGURE 3

INTENTION: COOL VENT STREAM TO 100 °F

GUIDE WORD:	Deviation	Cause	Consequence	Action
NO	Stream 11	Upstream valve shutoff	No heat transfer; waste of cooling water	Shut off cooling water
	Cooling Water	Temperature controller malfunction	No heat transfer	Replace temperature controller
MORE OF	Stream 11	Increase in upstream pressure and temperature	Insufficient heat transfer	Increase cooling water flowrate
	Cooling water	Increase in cooling water flowrate; valve malfunction; temperature controller malfunction	Too much heat transfer; waste of cooling water	Adjust valve to cooling water
	Stream 10 or cooling water temperature	Ambient conditions; increase in reactor temperature	Insufficient heat transfer	Increase cooling water flowrate
	Stream 11 pressure	Upstream valve malfunction	Increased temperature & flowrate; insufficient heat transfer	Increase cooling water flowrate
	Cooling water pressure	Ambient conditions	Insufficient heat transfer	Increase cooling water flowrate
LESS OF	Stream 11	Upstream valve malfunction; upstream process issue	Too much heat transfer; waste of cooling water	Reduce cooling water flowrate
	Cooling water	Cooling water valve malfunction; temperature controller malfunction	Insufficient heat transfer	Increase cooling water flowrate
	Stream 11 temperature	Upstream process issue; ambient conditions	Too much heat transfer; waste of cooling water	Reduce cooling water flowrate
	Stream 11 pressure	Upstream valve or process malfunction	Lowered Stream 11 temperature; too much heat transfer; waste of cooling water	Reduce cooling water flow
	Cooling water pressure	Ambient conditions	Insufficient heat transfer	Increase cooling water flowrate
AS WELL AS	Nylon in line	No probable cause		
REVERSE	Reversal of flow from Stream 12 into Stream 11	No probable cause		

PROCESS UNIT: VLV-102 A/B, VENT STREAM MIXING VALVE, FIGURE 3

INTENTION: COMBINE VENT STREAMS 6 AND 9

GUIDE WORD:	Deviation	Cause	Consequence	Action
NO	Stream 6 flowrate	Upstream shutdown	Reduced Stream 11 flowrate	No action
	Stream 9 flowrate	Upstream shutdown	Reduced Stream 11 flowrate	No action
MORE OF	Stream 6 flowrate	Surge of vent	Increased Stream 11 flowrate	Adjust valve
	Stream 9 flowrate	Surge of vent	Increased Stream 11 flowrate	Adjust valve
	Higher temperature	Increased reactor temperature	Raised pressures and flowrates in Streams 6, 9, & 11	Adjust valve
	Higher pressure	Increased reactor pressure; downstream blockage	Raised temperatures and flowrates in Streams 6, 9, & 11	Adjust valve
LESS OF	Stream 6 flowrate	Lowered conversion	Reduced Stream 11 flowrate	Adjust valve
	Stream 9 flowrate	Lowered conversion	Reduced Stream 11 flowrate	Adjust valve
	Lower temperature	Reactor heating failure	Reduced Stream 11 flowrate; lowered temperature	Adjust valve
	Lower pressure	Reactor heating failure	Reduced Stream 11 flowrate; lowered pressure	Adjust valve
AS WELL AS	Air in Stream 6	Pipe Leak	Two-phase mixture	No Action
	Air in Stream 9	Pipe Leak	Two-phase mixture	No Action
REVERSE	Reversal of Stream 6	No probable cause		
	Reversal of Stream 9	No probable cause		
OTHER THAN	Impurities	No probable cause		

PROCESS UNIT: E-103 A/B, AIR COOLER, FIGURE 3

INTENTION: COOL NYLON 6,6 PELLETS LEAVING X-101				
GUIDE WORD:	**Deviation**	**Cause**	**Consequence**	**Action**
NO	Stream 13 flow	Upstream valve shutoff	No pellets	Open control valve on Stream 10
	Air flow	Fan malfunction	Increased pellet temperature, non-uniformity of pellets	
MORE OF	Stream 13 flow	Increase in upstream pressure and temperature	Insufficient heat transfer, increased pellet temperature, non-unformity of pellets	Close control valve on Stream 10
	Air flow	Fan speed increase	Decreased pellet temperature	None
	Stream 13 temperature	Temperature controller malfunction on R-102; ambient conditions	Increased pellet temperature, non-uniformity of pellets; thermal degradation	Replace temperature control system on R-102
	Stream 13 pressure	Upstream valve malfunction; ambient conditions	Increased temperature & flowrate; insufficient heat transfer	Increase fan speed
	Air stream pressure	Fan speed increase; ambient conditions	Decreased pellet temperature	None
LESS OF	Stream 13 flow	Upstream valve malfunction; upstream process issue	Decreased pellet temperature, waste of utility use for fan	None
	Air flow	Fan speed decrease	Increased pellet temperature, non-uniformity of pellets	Increase fan speed
	Stream 13 temperature	Temperature controller malfunction on R-102, ambient conditions	Decreased pellet temperature, poor conversion	None
	Stream 13 pressure	Upstream valve malfunction; ambient conditions	Decreased temperature & flowrate; insufficient heat transfer	None
	Air stream pressure	Fan speed decrease; ambient conditions	Increased pellet temperature, non-uniformity of pellets; possible thermal degradation	Consider control system on fan speed
AS WELL AS	Air in Stream 13	Leak in process line	Pressure changes, non-uniformity of pellets	Replace process lines; repair leaks
REVERSE	Stream 13 reversed	No probable cause		
	Air flow reversed	Fan malfunction	None at this point in process	

PROCESS UNIT: X-101 A/B, NYLON PELLET EXTRUDER, FIGURE 3

INTENTION: CREATE NYLON PELLETS FROM MOLTEN NYLON STREAM				
GUIDE WORD:	**Deviation**	**Cause**	**Consequence**	**Action**
NO	Stream 10 flow	Upstream valve cut-off	No production; idle extruder	Open control valve on Stream 10
MORE OF	Stream 10 flow	Increase in upstream pressure and temperature	Larger pellets; possible extruder malfunction	Close control valve on Stream 10
	Stream 10 temperature	R-102 overheating; temperature controller malfunction ambient conditions;	Higher temperature pellets; possible thermal degradation	Replace temperature controller on R-102
	Stream 10 pressure	Upstream valve malfunction; ambient conditions	More dense pellets; possible extruder malfunction	Close control valve on Stream 10
LESS OF	Stream 10 flow	Decrease in upstream pressure and temperature	Smaller pellets; possible air bubbles	Open control valve on Stream 10
	Stream 10 temperature	R-102 underheating; temperature controller malfunction; ambient conditions	Lower temperature pellets; lower conversion	None
	Stream 10 pressure	Upstream valve malfunction; ambient conditions	Smaller pellets; possible air bubbles; slower production rate	None
AS WELL AS	Air in Stream 10	Leak in process line	Non-uniform pellets; air bubbles	Repair leak
REVERSE	Stream 10 reversed	No probable cause		

Manufacturing Costs

In order to more accurately assess which process was the most economically attractive, the manufacturing costs were estimated to account for any costs associated with day-to-day operation of the facility. Manufacturing costs for this project include operating labor cost, utilities, and water treatment.

To calculate the cost of operating labor, the number of non-particulate processing steps, N_{np}, must be determined.

$$N_{np} = \sum Equipment \qquad [20]$$

The number of operators required per shift can then be calculated using **Equation 21**, shown below.

$$N_{OL} = (6.29 + 31.7P^2 + 0.23N_{np})^{0.5} \qquad [21]$$

Where: N_{OL} = number of operators per shift
P = number of processing steps involving particulate solids
N_{np} = nonparticulate processing steps

The total number of operators that will need to be hired to cover all shifts can be calculated by using **Equation 22** and rounding up to the nearest integer.

$$N_{OL,total} = 4.5\ (N_{OL}) \qquad [22]$$

The total operating labor cost can then be calculated by multiplying by salary. The average salary for chemical plant operators is approximately $59,580 [19]. **Figure 39** shows the results of all calculations related to the cost of operating labor.

Operating Labor Cost	
Pieces of Equipment	8
Operators Required per Shift	2.85
Total Operators Required	13
Cost of Labor ($/yr)	$ 59,580
C_{OL} ($/yr)	$ 775,000

Figure 39: Operating Labor Costs

The cost for raw materials will be the same for both process options. The raw material cost was calculated using the prices shown in **Figure 40.**

Raw Material Costs		
	Unit Price ($/lbm)	Annual Price ($/yr)
Adipic Acid	$ 0.68	$ 37,00,000
Hexamethylenediamine	$ 1.14	$ 50,000,000

Figure 40: Raw Material Costs

Utility costs include the costs for cooling water, steam, or electricity requirements. Once the appropriate values for these requirements have been calculated, they can be multiplied by the unit price in order to yield the utility cost for a given piece of equipment. Summaries of the utility costs for the Batch/CSTR and PFR/CSTR options are given in **Figures 41** and **42**. The process vessel, V-101, does not use utilities, which is shown by 'X' in the figures.

Batch/CSTR Utility Costs	
P-101	$ 740
E-101	$ 128,000
R-101	$ 117,000
V-101	X
R-102	$ 17,000
E-102	$ 900,000
X-101	$ 32,000
E-103	$ 385,000

Figure 41: Batch/CSTR Process Utility Costs

PFR/CSTR Utility Costs	
P-101	$ 745
E-101	$ 128,000
R-101	$ 1,200,000
V-101	X
R-102	$ 17,000
E-102	$ 960,000
X-101	$ 32,000
E-103	$ 386,000

Figure 42: PFR/CSTR Process Utility Costs

This process includes a wastewater stream that must be treated before disposal. Similar to utility costs, the cost of this treatment is calculated by determining the amount of water to be treated and multiplying by the unit cost. Water treatment costs for the Batch/CSTR and PFR/CSTR options are shown in **Figures 43** and **44**.

Batch/CSTR Water Treatment Costs	
Water Removed (ft^3)	485,000
Water Treatment Cost ($/1000 ft^3)	$ 1.17
C_{WT} ($/yr)	$ 567

Figure 43: Batch/CSTR Process Water Treatment Costs

PFR/CSTR Water Treatment Costs	
Water Removed (ft^3)	480,000
Water Treatment Cost ($/1000 ft^3)	$ 1.17
C_{WT} ($/yr)	$ 562

Figure 44: PFR/CSTR Process Water Treatment Cost

Economic Analysis

For this project, the hurdle rate was assumed to be 15%, and the effective tax rate was assumed to be 40% [19]. The project was evaluated over 10 years using a 10 years MACRS depreciation. To avoid incurring the entire fixed capital cost in the first year of the project life, the cost was split evenly between Year 1 (2018) and Year 2 (2019).

Important capital and manufacturing costs were discussed in previous sections for both the Batch/CSTR and PFR/CSTR processes. The costs for each process at both 100% and 67% capacity are shown in **Figures 45 - 48**.

Batch/CSTR Cost Summary - 100%	
Total Capital Investment	$ 4,025,000
Operating Labor Cost	$ 775,000
Raw Materials	$ 87,000,000
Utility Cost	$ 1,600,000
Water Treatment	$ 570

Figure 45: Full Capacity Batch/CSTR Annual Cost Summary

Batch/CSTR Cost Summary - 67%	
Total Capital Investment	$ 4,025,000
Operating Labor Cost	$ 775,000
Raw Materials	$ 58,000,000
Utility Cost	$ 1,100,000
Water Treatment	$ 380

Figure 46: 67% Capacity Batch/CSTR Annual Cost Summary

PFR/CSTR Cost Summary - 100%	
Total Capital Investment	$ 4,600,000
Operating Labor Cost	$ 775,000
Raw Materials	$ 87,000,000
Utility Cost	$ 2,600,000
Wastewater Treatment	$ 570

Figure 47: Full Capacity PFR/CSTR Annual Cost Summary

PFR/CSTR Cost Summary - 67%	
Total Capital Investment	$ 4,600,000
Operating Labor Cost	$ 775,000
Raw Materials	$ 58,000,000
Utility Cost	$ 1,700,000
Wastewater Treatment	$ 380

Figure 48: 67% Capacity PFR/CSTR Annual Cost Summary

The annual production cost, which includes expenses related to the manufacturing of nylon 6,6, was calculated on an annual basis by summing the the costs of operating labor, raw materials, utilities, and wastewater treatment. That total was then divided by the total amount of nylon 6,6 produced per year to give the unit production cost, in $1.05/lbm. The annual and unit production costs are shown below in **Figure 49**.

Production Cost		
	Batch/CSTR	**PFR/CSTR**
Operating Labor (\$/yr)	\$ 775,000	\$ 775,000
Raw Materials (\$/yr)	\$ 87,000,000	\$ 87,000,000
Utilities (\$/yr)	\$ 1,600,000	\$ 2,600,000
Wastewater Treatment (\$/yr)	\$ 570	\$ 560
Annual Production Cost (\$/yr)	**\$ 89,300,000**	**\$ 90,400,000**
Unit Production Cost (\$/lb_m)	**\$ 1.05**	**\$ 1.06**

Figure 49: Production Cost Summary

The revenue was estimated using a production rate of 85,000,000 lbm/yr and \$1.45/lbm for nylon 6,6 [29]. The annual revenue for the plant is estimated to be \$123,250,000.

An incremental NPV analysis was completed to compare the Batch/CSTR and PFR/CSTR options at each specified production capacity, 100% and 67%. The incremental analysis was done by subtracting $NPV_{PFR/CSTR}$ from $NPV_{Batch/CSTR}$. The results of the incremental analysis indicate that the Batch/CSTR process is more economically attractive. **Figure 50** displays the results of the incremental analysis at 100% capacity, and the results for 67% are shown in **Figure 51.**

Incremental Analysis - 100%	
$NPV_{Batch/CSTR}$	\$ 73,360,000
$NPV_{PFR/CSTR}$	\$ 70,660,000
$NPV_{Batch-PFR}$	\$ \$2,700,000

Figure 50: 100 % Capacity Incremental Analysis

Incremental Analysis - 67%	
$NPV_{Batch/CSTR}$	\$ 48,270,000
$NPV_{PFR/CSTR}$	\$ 45,680,000
$NPV_{Batch-PFR}$	\$ 2,590,000

Figure 51: Turndown Incremental Analysis

The DCFROR for each case was also considered when comparing the two processes. The results of DCFROR calculations are summarized below in **Figure 52**.

DCFROR		
	Batch/CSTR	**PFR/CSTR**
100%	5.17%	4.11%
67%	4.86%	2.69%

Figure 52: DCFROR Summary

Once the Batch/CSTR option was chosen, a sensitivity analysis was performed to evaluate the effect of various changes on the overall economics of the project. In this analysis, each factor was varied by ±15%. Of the variables considered, the sale price of nylon 6,6 had the largest economic impact, while utility and labor costs had very low impacts. **Figure 53**, below, displays the results of the sensitivity analysis on the Batch/CSTR process.

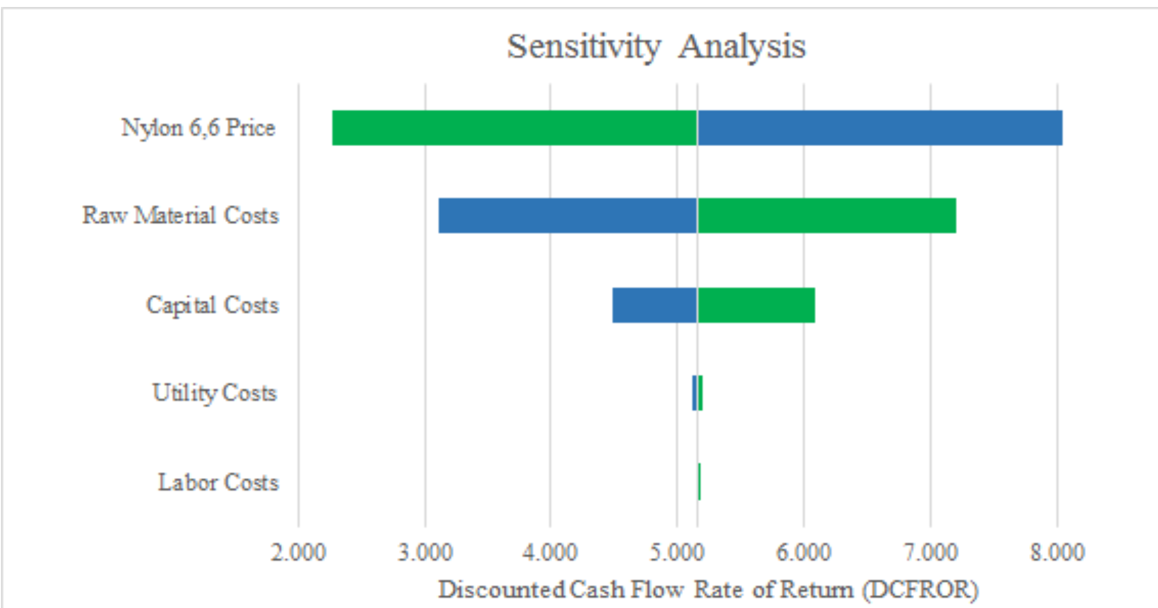


Figure 53: Sensitivity Analysis

Project Title: **100% Capacity Economic Evaluation - Batch/CSTR**

Corporate financial situation: Standalone

Internal rate of return, i* = 0.15

Other relevant project info. 10 Year MACRS Depreciation

=$1

Year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
End of Year	0	1	2	3	4	5	6	7	8	9	10
Net Revenue	0	0	61,625,000	123,250,000	123,250,000	123,250,000	123,250,000	123,250,000	123,250,000	123,250,000	123,250,000
-) Operating Cost			(44,957,752)	(89,915,505)	(89,915,505)	(89,915,505)	(89,915,505)	(89,915,505)	(89,915,505)	(89,915,505)	(89,915,505)
-) Depreciation		(167,773)	(469,764)	(543,584)	(434,867)	(347,961)	(278,335)	(233,540)	(219,782)	(219,950)	(165,088)
-) Loss Forward			(167,773)								
-) Writeoff											(55,029)
Taxable Income	0	0	16,029,711	32,790,911	32,899,628	32,986,534	33,056,160	33,100,955	33,114,713	33,114,545	33,114,377
-) Tax @ 40%	0	0	(6,411,884)	(13,116,365)	(13,159,851)	(13,194,614)	(13,222,464)	(13,240,382)	(13,245,885)	(13,245,818)	(13,245,751)
Net Income	0	0	9,617,827	19,674,547	19,739,777	19,791,921	19,833,696	19,860,573	19,868,828	19,868,727	19,868,626
+) Depreciation		0	469,764	543,584	434,867	347,961	278,335	233,540	219,782	219,950	165,088
+) Loss Forward			167,773								
+) Writeoff											55,029
-) Fixed Capital		(1,677,728)	(1,677,728)								
Cash Flow	0	(1,677,728)	8,577,635	20,218,130	20,174,644	20,139,881	20,112,031	20,094,113	20,088,610	20,088,677	20,088,744
Discount Factor (P/Fi*,n)	1.0000	0.8696	0.7561	0.6575	0.5718	0.4972	0.4323	0.3759	0.3269	0.2843	0.2472
Discounted Cash Flow	0	(1,458,894)	6,485,925	13,293,749	11,534,918	10,013,080	8,694,986	7,554,121	6,567,002	5,710,456	4,965,630

NPV @ i* =	73,360,974	Economic Interpretation of calculated NPV
DCFROR =	5.166	Economic Interpretation of calculated DCFROR

Project Title: **67% Capacity Economic Evaluation - Batch/CSTR**

Corporate financial situation: Standalone

Internal rate of return, i* = 0.15 or 15%

Other relevant project info. 10 Year MACRS Depreciation

1=$1

Year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
End of Year	0	1	2	3	4	5	6	7	8	9	10
Net Revenue	0	0	41,083,333	82,166,667	82,166,667	82,166,667	82,166,667	82,166,667	82,166,667	82,166,667	82,166,667
(-) Operating Cost			(30,100,925)	(60,201,850)	(60,201,850)	(60,201,850)	(60,201,850)	(60,201,850)	(60,201,850)	(60,201,850)	(60,201,850)
(-) Depreciation		(117,840)	(392,054)	(381,803)	(305,442)	(244,401)	(195,497)	(164,034)	(154,371)	(154,489)	(115,955)
(-) Loss Forward			(117,840)								
(-) Writeoff											(38,652)
Taxable Income	0	0	10,472,514	21,583,014	21,659,374	21,720,416	21,769,319	21,800,783	21,810,446	21,810,328	21,810,210
(-) Tax @ 40%	0	0	(4,189,006)	(8,633,206)	(8,663,750)	(8,688,166)	(8,707,728)	(8,720,313)	(8,724,178)	(8,724,131)	(8,724,084)
Net Income	0	0	6,283,508	12,949,808	12,995,625	13,032,249	13,061,592	13,080,470	13,086,267	13,086,197	13,086,126
(+) Depreciation		0	392,054	381,803	305,442	244,401	195,497	164,034	154,371	154,489	115,955
(+) Loss Forward			117,840								
(+) Writeoff											38,652
(-) Fixed Capital		(1,178,404)	(1,178,404)								
Cash Flow	0	(1,178,404)	5,614,999	13,331,611	13,301,067	13,276,650	13,257,089	13,244,504	13,240,638	13,240,686	13,240,733
Discount Factor (P/Fi*,n)	1.0000	0.8696	0.7561	0.6575	0.5718	0.4972	0.4323	0.3759	0.3269	0.2843	0.2472
Discounted Cash Flow	0	(1,024,699)	4,245,746	8,765,751	7,604,928	6,600,842	5,731,405	4,979,099	4,328,388	3,763,829	3,272,907
NPV @ i* =	48,268,196	Economic Interpretation of calculated NPV									
DCFROR =	4.858	conomic Interpretation of calculated DCFROF									

Project Title: **100% Capacity Economic Evaluation - PFR/CSTR**

Corporate financial situation: Standalone

Internal rate of return, i* = 0.15

Other relevant project info. 10 Year MACRS Depreciation

1=$1

Year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
End of Year	0	1	2	3	4	5	6	7	8	9	10
Net Revenue	0	0	61,625,000	123,250,000	123,250,000	123,250,000	123,250,000	123,250,000	123,250,000	123,250,000	123,250,000
(-) Operating Cost			(45,455,637)	(90,911,274)	(90,911,274)	(90,911,274)	(90,911,274)	(90,911,274)	(90,911,274)	(90,911,274)	(90,911,274)
(-) Depreciation		(204,452)	(572,467)	(662,426)	(529,941)	(424,034)	(339,187)	(284,598)	(267,833)	(268,037)	(201,181)
(-) Loss Forward			(204,452)								
(-) Writeoff											(67,060)
Taxable Income	0	0	15,392,444	31,676,300	31,808,785	31,914,692	31,999,539	32,054,128	32,070,893	32,070,689	32,070,484
(-) Tax @ 40%	0	0	(6,156,978)	(12,670,520)	(12,723,514)	(12,765,877)	(12,799,816)	(12,821,651)	(12,828,357)	(12,828,276)	(12,828,194)
Net Income	0	0	9,235,466	19,005,780	19,085,271	19,148,815	19,199,724	19,232,477	19,242,536	19,242,413	19,242,291
(+) Depreciation		0	572,467	662,426	529,941	424,034	339,187	284,598	267,833	268,037	201,181
(+) Loss Forward			204,452								
(+) Writeoff											67,060
(-) Fixed Capital		(2,044,524)	(2,044,524)								
Cash Flow	0	(2,044,524)	7,967,861	19,668,206	19,615,212	19,572,849	19,538,910	19,517,075	19,510,369	19,510,450	19,510,532
Discount Factor (P/Fi*,n)	1.0000	0.8696	0.7561	0.6575	0.5718	0.4972	0.4323	0.3759	0.3269	0.2843	0.2472
Discounted Cash Flow	0	(1,777,847)	6,024,848	12,932,165	11,215,061	9,731,165	8,447,210	7,337,191	6,377,974	5,546,088	4,822,705
NPV @ i* =	70,656,560	Economic Interpretation of calculated NPV									
DCFROR =	4.105	Economic Interpretation of calculated DCFROR									

Project Title: **67% Capacity Economic Evaluation - PFR/CSTR**

Corporate financial situation: Standalone

Internal rate of return, i* = 0.15 or 15%

Other relevant project info. 10 Year MACRS Depreciation

1=$1

Year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
End of Year	0	1	2	3	4	5	6	7	8	9	10
Net Revenue	0	0	41,083,333	82,166,667	82,166,667	82,166,667	82,166,667	82,166,667	82,166,667	82,166,667	82,166,667
(-) Operating Cost			(30,432,848)	(60,865,696)	(60,865,696)	(60,865,696)	(60,865,696)	(60,865,696)	(60,865,696)	(60,865,696)	(60,865,696)
(-) Depreciation		(204,452)	(572,467)	(662,426)	(529,941)	(424,034)	(339,187)	(284,598)	(267,833)	(268,037)	(201,181)
(-) Loss Forward			(204,452)								
(-) Writeoff											(67,060)
Taxable Income	0	0	9,873,566	20,638,545	20,771,030	20,876,936	20,961,784	21,016,373	21,033,138	21,032,934	21,032,729
(-) Tax @ 40%	0	0	(3,949,426)	(8,255,418)	(8,308,412)	(8,350,775)	(8,384,714)	(8,406,549)	(8,413,255)	(8,413,173)	(8,413,092)
Net Income	0	0	5,924,140	12,383,127	12,462,618	12,526,162	12,577,070	12,609,824	12,619,883	12,619,760	12,619,637
(+) Depreciation		0	572,467	662,426	529,941	424,034	339,187	284,598	267,833	268,037	201,181
(+) Loss Forward			204,452								
(+) Writeoff											67,060
(-) Fixed Capital		(2,044,524)	(2,044,524)								
Cash Flow	0	(2,044,524)	4,656,535	13,045,553	12,992,559	12,950,196	12,916,257	12,894,421	12,887,715	12,887,797	12,887,879
Discount Factor (P/Fi*,n)	1.0000	0.8696	0.7561	0.6575	0.5718	0.4972	0.4323	0.3759	0.3269	0.2843	0.2472
Discounted Cash Flow	0	(1,777,847)	3,521,009	8,577,663	7,428,538	6,438,536	5,584,054	4,847,491	4,213,017	3,663,516	3,185,687
NPV @ i* =	45,681,664	Economic Interpretation of calculated NPV									
DCFROR =	2.689	Economic Interpretation of calculated DCFROR									

Conclusions and Recommendations

The preliminary design assembled in this report produces the necessary 85 MM lbm/yr of nylon 6,6, and does so while producing a high profit margin. An economic analysis over a 10 year time period was completed on **Page 64** , and shows that the net present value for this design is $73,360,000 and the DCFROR is 5.17%. This design presents a hazard operability study on **Page 50** It is recommended that these analyses be completed in even more detail for the detailed design in order to maximize safety.

Total capital costs, including the grassroots factor, are $4.03 million, and are summarized on **Page 45**. Total manufacturing costs, including raw materials, are $89.3 million per year, and are given in more detail on **Page 61.** At the current estimated prices for nylon 6,6, this process will produce approximately $123.3 million in annual revenue in today's dollars. A summary list of equipment is given on **Page 22.**

This design made a number of assumptions that will need to be validated before proceeding. Most of these are involved in costing, and thus the design team recommends completing a more thorough costing analysis. Several assumptions and heuristics were used in the design of the process equipment. These range from area or volume calculations to how the equipment or reaction will behave. These heuristics will need to be validated, and the design team recommends a more thorough investigation into how the reaction and process equipment will behave under the specified conditions. In conclusion, the design team recommends that upper management proceed with a detailed design of the preliminary design provided in this report.

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Appendix

Capital Cost Summary Tables:

Batch/CSTR: P-101	
k_1	3.3892
k_2	0.0536
k_3	0.1538
C_1	X
C_2	X
C_3	X
F_p	1
F_m	1.55
B_1	1.89
B_2	1.35
$C_{p, 2016}$	**$ 6,200**
$C_{BM, 2016}$	**$ 16,000**

Batch/CSTR: E-101	
k_1	4.3247
k_2	-0.303
k_3	0.1634
C_1	0.03881
C_2	-0.11272
C_3	0.08183
F_p	1.021
F_m	1.8
B_1	1.63
B_2	1.63
$C_{p, 2016}$	**$ 38,000**
$C_{BM, 2016}$	**$ 96,000**

Batch/CSTR: R-101	
k_1	4.1052
k_2	0.532
k_3	-0.0005
C_1	X
C_2	X
C_3	X
F_p	X
F_m	X
B_1	X
B_2	X
$C_{p, 2016}$	**$ 66,000**
$C_{BM, 2016}$	**$ 265,000**

Batch/CSTR: V-101	
k_1	3.5565
k_2	0.3376
k_3	0.0905
C_1	X
C_2	X
C_3	X
F_p	1.308
F_m	1
B_1	1.49
B_2	1.52
$C_{p, 2016}$	**$ 8,800**
$C_{BM, 2016}$	**$ 23,500**

Batch/CSTR: R-102	
k_1	4.1052
k_2	0.532
k_3	-0.0005
C_1	X
C_2	X
C_3	X
F_p	X
F_m	X
B_1	X
B_2	X
$C_{p, 2016}$	**$ 76,500**
$C_{BM, 2016}$	**$ 306,000**

Batch/CSTR: E-102	
k_1	4.3247
k_2	-0.303
k_3	0.1634
C_1	X
C_2	X
C_3	X
F_p	1
F_m	1.8
B_1	1.63
B_2	1.63
$C_{p,\ 2016}$	**$ 54,000**
$C_{BM,\ 2016}$	**$ 138,000**

Batch/CSTR: E-103	
k_1	4.0336
k_2	0.2341
k_3	0.0497
C_1	X
C_2	X
C_3	X
F_p	1
F_m	1
B_1	1.63
B_2	1.63
$C_{p,\ 2016}$	**$ 32,500**
$C_{BM,\ 2016}$	**$ 106,100**

PFR/CSTR: P-101	
k_1	3.3892
k_2	0.0536
k_3	0.1538
C_1	X
C_2	X
C_3	X
F_p	1
F_m	1.55
B_1	1.89
B_2	1.35
$C_{p, 2016}$	**$ 6,200**
$C_{BM, 2016}$	**$ 16,000**

PFR/CSTR: E-101	
k_1	4.3247
k_2	-0.303
k_3	0.1634
C_1	0.03881
C_2	-0.11272
C_3	0.08183
F_p	1.021
F_m	1.8
B_1	1.63
B_2	1.63
$C_{p, 2016}$	**$ 38,000**
$C_{BM, 2016}$	**$ 96,000**

PFR/CSTR: R-101	
k_1	4.1052
k_2	0.532
k_3	-0.0005
C_1	X
C_2	X
C_3	X
F_p	X
F_m	X
B_1	X
B_2	X
$C_{p, 2016}$	**$ 75,000**
$C_{BM, 2016}$	**$ 290,000**

PFR/CSTR: V-101	
k_1	3.5565
k_2	0.3376
k_3	0.0905
C_1	X
C_2	X
C_3	X
F_p	1.292
F_m	1
B_1	1.49
B_2	1.52
$C_{p, 2016}$	**$ 8,700**
$C_{BM, 2016}$	**$ 23,000**

PFR/CSTR: R-102	
k_1	4.1052
k_2	0.532
k_3	-0.0005
C_1	X
C_2	X
C_3	X
F_p	X
F_m	X
B_1	X
B_2	X
$C_{p, 2016}$	**$ 77,000**
$C_{BM, 2016}$	**$ 310,000**

PFR/CSTR: E-102	
k_1	4.3247
k_2	-0.303
k_3	0.1634
C_1	X
C_2	X
C_3	X
F_p	1
F_m	1.8
B_1	1.63
B_2	1.63
$C_{p, 2016}$	**$ 50,000**
$C_{BM, 2016}$	**$ 130,000**

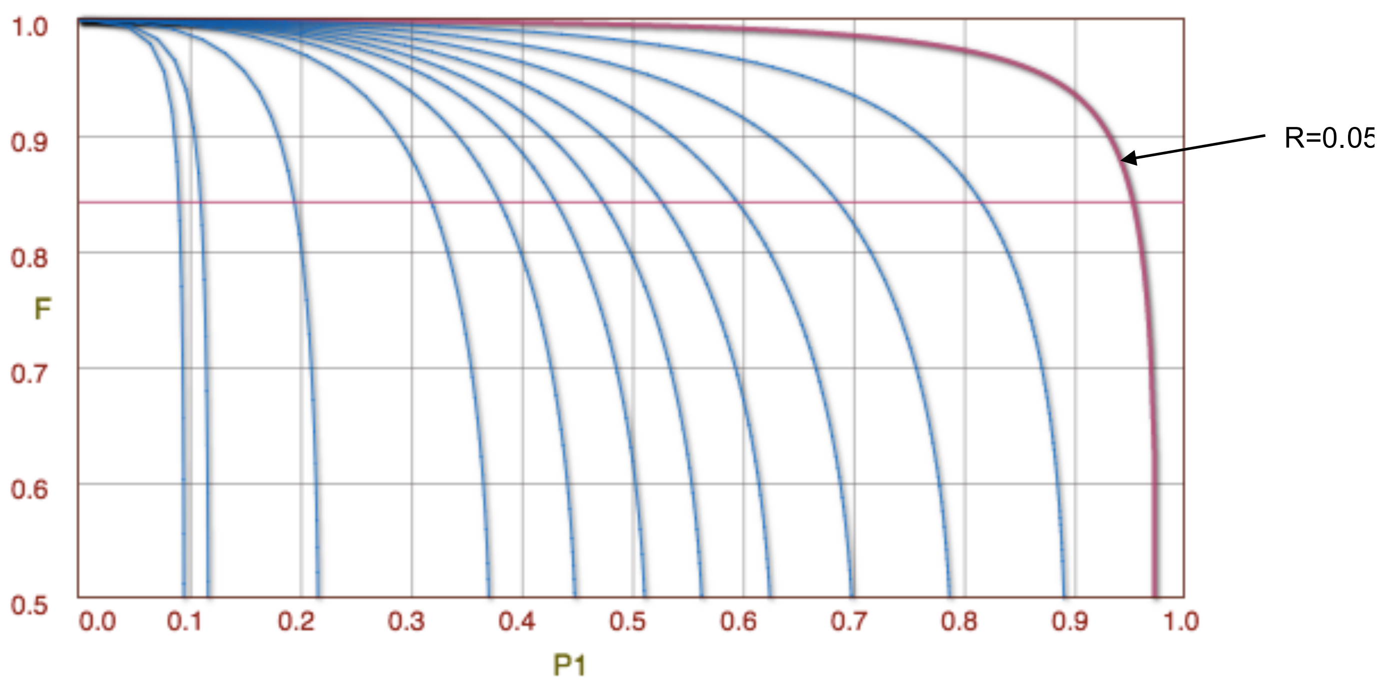
PFR/CSTR: E-103	
k_1	4.0336
k_2	0.2341
k_3	0.0497
C_1	X
C_2	X
C_3	X
F_p	1
F_m	1
B_1	1.63
B_2	1.63
$C_{p, 2016}$	**$ 35,000**
$C_{BM, 2016}$	**$ 115,000**

Correction factor E-102.

$$R = \frac{t1 - t2}{T2 - T1} = \frac{87 - 100}{100 - 363} = 0.05$$

$$R = \frac{T2 - T1}{t1 - T1} = \frac{100 - 363}{87 - 363} = 0.95$$

From the graph below, acquired from http://checalc.com/solved/LMTD_Chart.html, F is approximately 0.85.



Aspen Design File:

ADA CMBVENT FEED HDMA LIQ-NY66

STREAM ID	ADA	CMBVENT	FEED	HDMA	LIQ-NY66
FROM :	----	B1	FEED-HEX	----	CSTR2
TO :	MIXER	C1	BATCH	MIXER	AIR-COOL
SUBSTREAM: MIXED					
PHASE:	LIQUID	VAPOR	LIQUID	LIQUID	LIQUID
COMPONENTS: LBMOL/HR					
NYLON-01	0.0	0.0	0.0	0.0	45.2540
ADA	45.3728	3.8342-03	45.3728	0.0	3.6460-03
HDMA	0.0	0.3492	45.3761	45.3761	9.3381-05
WATER	52.9185	195.3146	105.7903	52.8719	0.4196
COMPONENTS: LB/HR					
NYLON-01	0.0	0.0	0.0	0.0	1.0242+04
ADA	6630.9138	0.5603	6630.9138	0.0	0.5328
HDMA	0.0	40.5805	5272.9985	5272.9985	1.0852-02
WATER	953.3408	3518.6479	1905.8423	952.5015	7.5597
TOTAL FLOW:					
LBMOL/HR	98.2912	195.6677	196.5392	98.2480	45.6774
LB/HR	7584.2546	3559.7888	1.3810+04	6225.5000	1.0250+04
CUFT/HR	108.5036	2.0678+05	262.2665	114.7559	189.6096
STATE VARIABLES:					
TEMP F	140.0000	362.8154	410.0000	140.0000	518.0000
PRES PSIA	14.6959	8.3326	117.5676	14.6959	8.3326
VFRAC	0.0	1.0000	0.0	0.0	0.0
LFRAC	1.0000	0.0	1.0000	1.0000	1.0000
SFRAC	0.0	0.0	0.0	0.0	0.0
ENTHALPY:					
BTU/LBMOL	-2.5611+05	-1.0152+05	-1.6304+05	-9.3840+04	-1.0955+05
BTU/LB	-3319.1718	-5580.0498	-2320.4177	-1480.9353	-488.2080
BTU/HR	-2.5173+07	-1.9864+07	-3.2044+07	-9.2196+06	-5.0041+06
ENTROPY:					
BTU/LBMOL-R	-100.7042	-6.2827	-91.9409	-116.0859	-248.0096
BTU/LB-R	-1.3051	-0.3453	-1.3085	-1.8320	-1.1052
DENSITY:					
LBMOL/CUFT	0.9059	9.4628-04	0.7494	0.8561	0.2409
LB/CUFT	69.8986	1.7216-02	52.6554	54.2499	54.0582
AVG MW	77.1610	18.1930	70.2646	63.3652	224.3987
COMPONENT ATTRIBUTES:					
NYLON-01 SFRAC					

```
     E-ADA       MISSING  8.7005-03     0.0       MISSING  8.7005-03
     R-ADA       MISSING     0.4932     0.0       MISSING     0.4932
     E-HDMA      MISSING  1.2108-03     0.0       MISSING  1.2108-03
     R-HDMA      MISSING     0.4969     0.0       MISSING     0.4969
    SFLOW
     E-ADA       MISSING     0.0        0.0       MISSING     0.7865
     R-ADA       MISSING     0.0        0.0       MISSING    44.5788
     E-HDMA      MISSING     0.0        0.0       MISSING     0.1094
     R-HDMA      MISSING     0.0        0.0       MISSING    44.9173
    EFRAC
     E-ADA       MISSING     0.8778     0.0       MISSING     0.8778
     E-HDMA      MISSING     0.1222     0.0       MISSING     0.1222
    ZMOM
     ZMOM        MISSING     0.0        0.0       MISSING     0.4479
    FMOM
     FMOM        MISSING     0.0        0.0       MISSING    90.3920
    DPN
     DPN         MISSING   201.7905     0.0       MISSING   201.7905
    MWN
     MWN         MISSING  2.2864+04     0.0       MISSING  2.2864+04

NYLON-66 OLIG RAW-FEED UNHEAT-F VENT1
-------------------------------------

STREAM ID            NYLON-66   OLIG      RAW-FEED   UNHEAT-F   VENT1
FROM :               AIR-COOL   BATCH     MIXER      FEED-PUM   BATCH
TO   :               ----       CSTR2     FEED-PUM   FEED-HEX   B1

SUBSTREAM: MIXED
PHASE:               LIQUID     LIQUID    LIQUID     LIQUID     VAPOR
COMPONENTS: LBMOL/HR
  NYLON-01            45.2540    45.3029     0.0        0.0        0.0
  ADA               3.6460-03  1.2400-02   45.3728    45.3728  3.6124-03
  HDMA              9.3381-05  3.6955-03   45.3761    45.3761     0.3491
  WATER                0.4196     6.8571  105.7903   105.7903   188.1712
COMPONENTS: LB/HR
  NYLON-01          1.0242+04  1.0253+04     0.0        0.0        0.0
  ADA                  0.5328     1.8121 6630.9138  6630.9138     0.5279
  HDMA              1.0852-02     0.4294 5272.9985  5272.9985    40.5629
  WATER                7.5597   123.5332 1905.8423  1905.8423  3389.9574
TOTAL FLOW:
  LBMOL/HR            45.6774    52.1762  196.5392   196.5392   188.5239
  LB/HR             1.0250+04  1.0379+04 1.3810+04  1.3810+04  3431.0482
  CUFT/HR            167.9774   192.4994  223.2077   223.3439  1.3436+04
```

```
STATE VARIABLES:
  TEMP   F          140.0000   518.1727   140.0000   141.2137   373.8252
  PRES   PSIA        14.6959   121.2416    14.6959   120.0000   121.2416
  VFRAC               0.0        0.0        0.0        0.0        1.0000
  LFRAC               1.0000     1.0000     1.0000     1.0000     0.0
  SFRAC               0.0        0.0        0.0        0.0        0.0
ENTHALPY:
  BTU/LBMOL         -1.5898+05 -1.1168+05 -1.7499+05 -1.7493+05 -1.0156+05
  BTU/LB          -708.4648  -561.4262 -2490.4864 -2489.5864 -5580.5017
  BTU/HR          -7.2617+06 -5.8269+06 -3.4393+07 -3.4381+07 -1.9147+07
ENTROPY:
  BTU/LBMOL-R       -311.3551  -220.0114  -107.7578  -107.6528   -11.6068
  BTU/LB-R            -1.3875    -1.1061    -1.5336    -1.5321    -0.6378
DENSITY:
  LBMOL/CUFT           0.2719     0.2710     0.8805     0.8800  1.4031-02
  LB/CUFT             61.0198    53.9154    61.8695    61.8318     0.2554
AVG MW               224.3987   198.9163    70.2646    70.2646    18.1995
COMPONENT ATTRIBUTES:
NYLON-01 SFRAC
        E-ADA    8.7005-03  1.6323-02   MISSING    MISSING    MISSING
        R-ADA       0.4932     0.4855   MISSING    MISSING    MISSING
        E-HDMA   1.2108-03  8.9450-03   MISSING    MISSING    MISSING
        R-HDMA      0.4969     0.4892   MISSING    MISSING    MISSING
       SFLOW
        E-ADA       0.7865     1.4753   MISSING    MISSING    MISSING
        R-ADA      44.5788    43.8814   MISSING    MISSING    MISSING
        E-HDMA      0.1094     0.8085   MISSING    MISSING    MISSING
        R-HDMA     44.9173    44.2148   MISSING    MISSING    MISSING
       EFRAC
        E-ADA       0.8778     0.6460   MISSING    MISSING    MISSING
        E-HDMA      0.1222     0.3540   MISSING    MISSING    MISSING
       ZMOM
        ZMOM        0.4479     1.1419   MISSING    MISSING    MISSING
       FMOM
        FMOM       90.3920    90.3800   MISSING    MISSING    MISSING
       DPN
        DPN       201.7905    79.1508   MISSING    MISSING    MISSING
       MWN
        MWN      2.2864+04  8979.0516   MISSING    MISSING    MISSING

VENT2 WASTEH20
--------------

STREAM ID           VENT2      WASTEH20
```

FROM : CSTR2 C1
TO : B1 ----

SUBSTREAM: MIXED

PHASE:	VAPOR	LIQUID
COMPONENTS: LBMOL/HR		
NYLON-01	0.0	0.0
ADA	2.2176-04	3.8342-03
HDMA	1.5164-04	0.3492
WATER	7.1434	195.3146
COMPONENTS: LB/HR		
NYLON-01	0.0	0.0
ADA	3.2409-02	0.5603
HDMA	1.7621-02	40.5805
WATER	128.6906	3518.6479
TOTAL FLOW:		
LBMOL/HR	7.1438	195.6677
LB/HR	128.7406	3559.7888
CUFT/HR	8981.7960	58.2305
STATE VARIABLES:		
TEMP F	518.0000	100.0000
PRES PSIA	8.3326	14.7000
VFRAC	1.0000	0.0
LFRAC	0.0	1.0000
SFRAC	0.0	0.0
ENTHALPY:		
BTU/LBMOL	-1.0034+05	-1.2236+05
BTU/LB	-5568.0063	-6725.8552
BTU/HR	-7.1683+05	-2.3943+07
ENTROPY:		
BTU/LBMOL-R	-4.5678	-38.5142
BTU/LB-R	-0.2535	-2.1170
DENSITY:		
LBMOL/CUFT	7.9536-04	3.3602
LB/CUFT	1.4334-02	61.1328
AVG MW	18.0213	18.1930
COMPONENT ATTRIBUTES:		
NYLON-01 SFRAC		
E-ADA	8.7005-03	8.7005-03
R-ADA	0.4932	0.4932
E-HDMA	1.2108-03	1.2108-03
R-HDMA	0.4969	0.4969
SFLOW		
E-ADA	0.0	0.0

```
     R-ADA        0.0        0.0
     E-HDMA       0.0        0.0
     R-HDMA       0.0        0.0
    EFRAC
     E-ADA        0.8778     0.8778
     E-HDMA       0.1222     0.1222
    ZMOM
     ZMOM         0.0        0.0
    FMOM
     FMOM         0.0        0.0
    DPN
     DPN        201.7905   201.7905
    MWN
     MWN       2.2864+04  2.2864+04

ADA
---

STREAM ID             ADA
FROM :                ----
TO   :                MIXER

SUBSTREAM: MIXED
PHASE:                LIQUID
COMPONENTS: LBMOL/HR
  NYLON-01              0.0
  ADA                  45.3728
  HDMA                  0.0
  WATER                52.9185
COMPONENTS: LB/HR
  NYLON-01              0.0
  ADA                6630.9138
  HDMA                  0.0
  WATER               953.3408
TOTAL FLOW:
  LBMOL/HR             98.2912
  LB/HR              7584.2546
  CUFT/HR             108.5036
STATE VARIABLES:
  TEMP   F            140.0000
  PRES   PSIA          14.6959
  VFRAC                 0.0
  LFRAC                 1.0000
  SFRAC                 0.0
```

```
ENTHALPY:
  BTU/LBMOL         -2.5611+05
  BTU/LB           -3319.1718
  BTU/HR           -2.5173+07
ENTROPY:
  BTU/LBMOL-R        -100.7042
  BTU/LB-R            -1.3051
DENSITY:
  LBMOL/CUFT           0.9059
  LB/CUFT             69.8986
AVG MW                77.1610
COMPONENT ATTRIBUTES:
NYLON-01 SFRAC
         SFLOW
         EFRAC
         ZMOM
         FMOM
         DPN
         MWN

CMBVENT
-------

STREAM ID             CMBVENT
FROM :                 B1
TO   :                 C1

SUBSTREAM: MIXED
PHASE:                VAPOR
COMPONENTS: LBMOL/HR
  NYLON-01              0.0
  ADA                3.8342-03
  HDMA                 0.3492
  WATER              195.3146
COMPONENTS: LB/HR
  NYLON-01              0.0
  ADA                  0.5603
  HDMA                40.5805
  WATER             3518.6479
TOTAL FLOW:
  LBMOL/HR           195.6677
  LB/HR            3559.7888
  CUFT/HR           2.0678+05
STATE VARIABLES:
```

TEMP F 362.8154
PRES PSIA 8.3326
VFRAC 1.0000
LFRAC 0.0
SFRAC 0.0
ENTHALPY:
BTU/LBMOL -1.0152+05
BTU/LB -5580.0498
BTU/HR -1.9864+07
ENTROPY:
BTU/LBMOL-R -6.2827
BTU/LB-R -0.3453
DENSITY:
LBMOL/CUFT 9.4628-04
LB/CUFT 1.7216-02
AVG MW 18.1930
COMPONENT ATTRIBUTES:
NYLON-01 SFRAC
E-ADA 8.7005-03
R-ADA 0.4932
E-HDMA 1.2108-03
R-HDMA 0.4969
SFLOW
E-ADA 0.0
R-ADA 0.0
E-HDMA 0.0
R-HDMA 0.0
EFRAC
E-ADA 0.8778
E-HDMA 0.1222
ZMOM
ZMOM 0.0
FMOM
FMOM 0.0
DPN
DPN 201.7905
MWN
MWN 2.2864+04

FEED

STREAM ID FEED
FROM : FEED-HEX

TO : BATCH

SUBSTREAM: MIXED
PHASE: LIQUID
COMPONENTS: LBMOL/HR
NYLON-01 0.0
ADA 45.3728
HDMA 45.3761
WATER 105.7903
COMPONENTS: LB/HR
NYLON-01 0.0
ADA 6630.9138
HDMA 5272.9985
WATER 1905.8423
TOTAL FLOW:
LBMOL/HR 196.5392
LB/HR 1.3810+04
CUFT/HR 262.2665
STATE VARIABLES:
TEMP F 410.0000
PRES PSIA 117.5676
VFRAC 0.0
LFRAC 1.0000
SFRAC 0.0
ENTHALPY:
BTU/LBMOL -1.6304+05
BTU/LB -2320.4177
BTU/HR -3.2044+07
ENTROPY:
BTU/LBMOL-R -91.9409
BTU/LB-R -1.3085
DENSITY:
LBMOL/CUFT 0.7494
LB/CUFT 52.6554
AVG MW 70.2646
COMPONENT ATTRIBUTES:
NYLON-01 SFRAC
E-ADA 0.0
R-ADA 0.0
E-HDMA 0.0
R-HDMA 0.0
SFLOW
E-ADA 0.0
R-ADA 0.0

```
       E-HDMA       0.0
       R-HDMA       0.0
      EFRAC
       E-ADA        0.0
       E-HDMA       0.0
      ZMOM
       ZMOM         0.0
      FMOM
       FMOM         0.0
      DPN
       DPN          0.0
      MWN
       MWN          0.0

HDMA
----

STREAM ID              HDMA
FROM :                 ----
TO   :                 MIXER

SUBSTREAM: MIXED
PHASE:                 LIQUID
COMPONENTS: LBMOL/HR
  NYLON-01             0.0
  ADA                  0.0
  HDMA                 45.3761
  WATER                52.8719
COMPONENTS: LB/HR
  NYLON-01             0.0
  ADA                  0.0
  HDMA                 5272.9985
  WATER                952.5015
TOTAL FLOW:
  LBMOL/HR             98.2480
  LB/HR                6225.5000
  CUFT/HR              114.7559
STATE VARIABLES:
  TEMP   F             140.0000
  PRES   PSIA          14.6959
  VFRAC                0.0
  LFRAC                1.0000
  SFRAC                0.0
ENTHALPY:
```

```
  BTU/LBMOL         -9.3840+04
  BTU/LB           -1480.9353
  BTU/HR            -9.2196+06
ENTROPY:
  BTU/LBMOL-R        -116.0859
  BTU/LB-R            -1.8320
DENSITY:
  LBMOL/CUFT           0.8561
  LB/CUFT             54.2499
AVG MW                63.3652
COMPONENT ATTRIBUTES:
NYLON-01 SFRAC
        SFLOW
        EFRAC
        ZMOM
        FMOM
        DPN
        MWN

LIQ-NY66
--------

STREAM ID             LIQ-NY66
FROM :                CSTR2
TO   :                AIR-COOL

SUBSTREAM: MIXED
PHASE:                LIQUID
COMPONENTS: LBMOL/HR
  NYLON-01            45.2540
  ADA               3.6460-03
  HDMA              9.3381-05
  WATER               0.4196
COMPONENTS: LB/HR
  NYLON-01          1.0242+04
  ADA                 0.5328
  HDMA              1.0852-02
  WATER               7.5597
TOTAL FLOW:
  LBMOL/HR            45.6774
  LB/HR             1.0250+04
  CUFT/HR            189.6096
STATE VARIABLES:
  TEMP   F           518.0000
```

PRES PSIA 8.3326
VFRAC 0.0
LFRAC 1.0000
SFRAC 0.0
ENTHALPY:
BTU/LBMOL -1.0955+05
BTU/LB -488.2080
BTU/HR -5.0041+06
ENTROPY:
BTU/LBMOL-R -248.0096
BTU/LB-R -1.1052
DENSITY:
LBMOL/CUFT 0.2409
LB/CUFT 54.0582
AVG MW 224.3987
COMPONENT ATTRIBUTES:
NYLON-01 SFRAC
E-ADA 8.7005-03
R-ADA 0.4932
E-HDMA 1.2108-03
R-HDMA 0.4969
SFLOW
E-ADA 0.7865
R-ADA 44.5788
E-HDMA 0.1094
R-HDMA 44.9173
EFRAC
E-ADA 0.8778
E-HDMA 0.1222
ZMOM
ZMOM 0.4479
FMOM
FMOM 90.3920
DPN
DPN 201.7905
MWN
MWN 2.2864+04

NYLON-66

STREAM ID NYLON-66
FROM : AIR-COOL
TO : ----

SUBSTREAM: MIXED
PHASE: LIQUID
COMPONENTS: LBMOL/HR

NYLON-01	45.2540
ADA	3.6460-03
HDMA	9.3381-05
WATER	0.4196

COMPONENTS: LB/HR

NYLON-01	1.0242+04
ADA	0.5328
HDMA	1.0852-02
WATER	7.5597

TOTAL FLOW:

LBMOL/HR	45.6774
LB/HR	1.0250+04
CUFT/HR	167.9774

STATE VARIABLES:

TEMP F	140.0000
PRES PSIA	14.6959
VFRAC	0.0
LFRAC	1.0000
SFRAC	0.0

ENTHALPY:

BTU/LBMOL	-1.5898+05
BTU/LB	-708.4648
BTU/HR	-7.2617+06

ENTROPY:

BTU/LBMOL-R	-311.3551
BTU/LB-R	-1.3875

DENSITY:

LBMOL/CUFT	0.2719
LB/CUFT	61.0198

AVG MW 224.3987
COMPONENT ATTRIBUTES:
NYLON-01 SFRAC

E-ADA	8.7005-03
R-ADA	0.4932
E-HDMA	1.2108-03
R-HDMA	0.4969

SFLOW

E-ADA	0.7865
R-ADA	44.5788
E-HDMA	0.1094

```
    R-HDMA      44.9173
   EFRAC
    E-ADA       0.8778
    E-HDMA       0.1222
   ZMOM
    ZMOM        0.4479
   FMOM
    FMOM        90.3920
   DPN
    DPN       201.7905
   MWN
    MWN       2.2864+04

OLIG
----

STREAM ID             OLIG
FROM :              BATCH
TO   :             CSTR2

SUBSTREAM: MIXED
PHASE:              LIQUID
COMPONENTS: LBMOL/HR
 NYLON-01           45.3029
 ADA              1.2400-02
 HDMA              3.6955-03
 WATER              6.8571
COMPONENTS: LB/HR
 NYLON-01          1.0253+04
 ADA               1.8121
 HDMA              0.4294
 WATER             123.5332
TOTAL FLOW:
 LBMOL/HR           52.1762
 LB/HR            1.0379+04
 CUFT/HR           192.4994
STATE VARIABLES:
 TEMP   F          518.1727
 PRES   PSIA         121.2416
 VFRAC              0.0
 LFRAC              1.0000
 SFRAC              0.0
ENTHALPY:
 BTU/LBMOL         -1.1168+05
```

BTU/LB -561.4262
BTU/HR -5.8269+06
ENTROPY:
BTU/LBMOL-R -220.0114
BTU/LB-R -1.1061
DENSITY:
LBMOL/CUFT 0.2710
LB/CUFT 53.9154
AVG MW 198.9163
COMPONENT ATTRIBUTES:
NYLON-01 SFRAC
E-ADA 1.6323-02
R-ADA 0.4855
E-HDMA 8.9450-03
R-HDMA 0.4892
SFLOW
E-ADA 1.4753
R-ADA 43.8814
E-HDMA 0.8085
R-HDMA 44.2148
EFRAC
E-ADA 0.6460
E-HDMA 0.3540
ZMOM
ZMOM 1.1419
FMOM
FMOM 90.3800
DPN
DPN 79.1508
MWN
MWN 8979.0516

RAW-FEED

STREAM ID RAW-FEED
FROM : MIXER
TO : FEED-PUM

SUBSTREAM: MIXED
PHASE: LIQUID
COMPONENTS: LBMOL/HR
NYLON-01 0.0
ADA 45.3728

HDMA	45.3761
WATER	105.7903
COMPONENTS: LB/HR	
NYLON-01	0.0
ADA	6630.9138
HDMA	5272.9985
WATER	1905.8423
TOTAL FLOW:	
LBMOL/HR	196.5392
LB/HR	1.3810+04
CUFT/HR	223.2077
STATE VARIABLES:	
TEMP F	140.0000
PRES PSIA	14.6959
VFRAC	0.0
LFRAC	1.0000
SFRAC	0.0
ENTHALPY:	
BTU/LBMOL	-1.7499+05
BTU/LB	-2490.4864
BTU/HR	-3.4393+07
ENTROPY:	
BTU/LBMOL-R	-107.7578
BTU/LB-R	-1.5336
DENSITY:	
LBMOL/CUFT	0.8805
LB/CUFT	61.8695
AVG MW	70.2646
COMPONENT ATTRIBUTES:	
NYLON-01 SFRAC	
SFLOW	
EFRAC	
ZMOM	
FMOM	
DPN	
MWN	

UNHEAT-F

STREAM ID	UNHEAT-F
FROM :	FEED-PUM
TO :	FEED-HEX

SUBSTREAM: MIXED
PHASE: LIQUID
COMPONENTS: LBMOL/HR

NYLON-01	0.0
ADA	45.3728
HDMA	45.3761
WATER	105.7903

COMPONENTS: LB/HR

NYLON-01	0.0
ADA	6630.9138
HDMA	5272.9985
WATER	1905.8423

TOTAL FLOW:

LBMOL/HR	196.5392
LB/HR	1.3810+04
CUFT/HR	223.3439

STATE VARIABLES:

TEMP F	141.2137
PRES PSIA	120.0000
VFRAC	0.0
LFRAC	1.0000
SFRAC	0.0

ENTHALPY:

BTU/LBMOL	-1.7493+05
BTU/LB	-2489.5864
BTU/HR	-3.4381+07

ENTROPY:

BTU/LBMOL-R	-107.6528
BTU/LB-R	-1.5321

DENSITY:

LBMOL/CUFT	0.8800
LB/CUFT	61.8318

AVG MW 70.2646
COMPONENT ATTRIBUTES:
NYLON-01 SFRAC
SFLOW
EFRAC
ZMOM
FMOM
DPN
MWN

VENT1

STREAM ID	VENT1
FROM :	BATCH
TO :	B1
SUBSTREAM: MIXED	
PHASE:	VAPOR
COMPONENTS: LBMOL/HR	
NYLON-01	0.0
ADA	3.6124-03
HDMA	0.3491
WATER	188.1712
COMPONENTS: LB/HR	
NYLON-01	0.0
ADA	0.5279
HDMA	40.5629
WATER	3389.9574
TOTAL FLOW:	
LBMOL/HR	188.5239
LB/HR	3431.0482
CUFT/HR	1.3436+04
STATE VARIABLES:	
TEMP F	373.8252
PRES PSIA	121.2416
VFRAC	1.0000
LFRAC	0.0
SFRAC	0.0
ENTHALPY:	
BTU/LBMOL	-1.0156+05
BTU/LB	-5580.5017
BTU/HR	-1.9147+07
ENTROPY:	
BTU/LBMOL-R	-11.6068
BTU/LB-R	-0.6378
DENSITY:	
LBMOL/CUFT	1.4031-02
LB/CUFT	0.2554
AVG MW	18.1995
COMPONENT ATTRIBUTES:	
NYLON-01 SFRAC	
SFLOW	
EFRAC	
ZMOM	
FMOM	

DPN
MWN

VENT2

STREAM ID	VENT2
FROM :	CSTR2
TO :	B1
SUBSTREAM: MIXED	
PHASE:	VAPOR
COMPONENTS: LBMOL/HR	
NYLON-01	0.0
ADA	2.2176-04
HDMA	1.5164-04
WATER	7.1434
COMPONENTS: LB/HR	
NYLON-01	0.0
ADA	3.2409-02
HDMA	1.7621-02
WATER	128.6906
TOTAL FLOW:	
LBMOL/HR	7.1438
LB/HR	128.7406
CUFT/HR	8981.7960
STATE VARIABLES:	
TEMP F	518.0000
PRES PSIA	8.3326
VFRAC	1.0000
LFRAC	0.0
SFRAC	0.0
ENTHALPY:	
BTU/LBMOL	-1.0034+05
BTU/LB	-5568.0063
BTU/HR	-7.1683+05
ENTROPY:	
BTU/LBMOL-R	-4.5678
BTU/LB-R	-0.2535
DENSITY:	
LBMOL/CUFT	7.9536-04
LB/CUFT	1.4334-02
AVG MW	18.0213
COMPONENT ATTRIBUTES:	

```
NYLON-01 SFRAC
     E-ADA      8.7005-03
     R-ADA        0.4932
     E-HDMA     1.2108-03
     R-HDMA       0.4969
    SFLOW
     E-ADA        0.0
     R-ADA        0.0
     E-HDMA       0.0
     R-HDMA       0.0
    EFRAC
     E-ADA        0.8778
     E-HDMA       0.1222
    ZMOM
     ZMOM         0.0
    FMOM
     FMOM         0.0
    DPN
     DPN        201.7905
    MWN
     MWN        2.2864+04

WASTEH20
--------

STREAM ID              WASTEH20
FROM :                 C1
TO   :                 ----

SUBSTREAM: MIXED
PHASE:                 LIQUID
COMPONENTS: LBMOL/HR
 NYLON-01              0.0
 ADA                 3.8342-03
 HDMA                  0.3492
 WATER               195.3146
COMPONENTS: LB/HR
 NYLON-01              0.0
 ADA                   0.5603
 HDMA                 40.5805
 WATER              3518.6479
TOTAL FLOW:
 LBMOL/HR            195.6677
 LB/HR              3559.7888
```

CUFT/HR 58.2305
STATE VARIABLES:
TEMP F 100.0000
PRES PSIA 14.7000
VFRAC 0.0
LFRAC 1.0000
SFRAC 0.0
ENTHALPY:
BTU/LBMOL -1.2236+05
BTU/LB -6725.8552
BTU/HR -2.3943+07
ENTROPY:
BTU/LBMOL-R -38.5142
BTU/LB-R -2.1170
DENSITY:
LBMOL/CUFT 3.3602
LB/CUFT 61.1328
AVG MW 18.1930
COMPONENT ATTRIBUTES:
NYLON-01 SFRAC
E-ADA 8.7005-03
R-ADA 0.4932
E-HDMA 1.2108-03
R-HDMA 0.4969
SFLOW
E-ADA 0.0
R-ADA 0.0
E-HDMA 0.0
R-HDMA 0.0
EFRAC
E-ADA 0.8778
E-HDMA 0.1222
ZMOM
ZMOM 0.0
FMOM
FMOM 0.0
DPN
DPN 201.7905
MWN
MWN 2.2864+04

BLOCK: AIR-COOL MODEL: HEATER

```
 INLET STREAM:        LIQ-NY66
 OUTLET STREAM:       NYLON-66
 PROPERTY OPTION SET:  POLYNRTL  POLYMER NRTL / REDLICH-KWONG

            ***  MASS AND ENERGY BALANCE  ***
                      IN           OUT       RELATIVE DIFF.
  TOTAL BALANCE
    MOLE(LBMOL/HR)        45.6774       45.6774       0.00000
    MASS(LB/HR   )        10250.0       10250.0      -0.177463E-15
    ENTHALPY(BTU/HR  )   -0.500411E+07  -0.726173E+07   0.310893

            ***  CO2 EQUIVALENT SUMMARY ***
  FEED STREAMS CO2E           0.00000      LB/HR
  PRODUCT STREAMS CO2E        0.00000      LB/HR
  NET STREAMS CO2E PRODUCTION  0.00000      LB/HR
  UTILITIES CO2E PRODUCTION    0.00000      LB/HR
  TOTAL CO2E PRODUCTION        0.00000      LB/HR

              ***  INPUT DATA  ***
 ONE   PHASE  TP  FLASH   SPECIFIED PHASE IS  LIQUID
 SPECIFIED TEMPERATURE            F                  140.000
 SPECIFIED PRESSURE             PSIA                 14.6959
 MAXIMUM NO. ITERATIONS                              30
 CONVERGENCE TOLERANCE                                  0.000100000



              ***  RESULTS  ***
 OUTLET TEMPERATURE    F                        140.00
 OUTLET PRESSURE      PSIA                      14.696
 HEAT DUTY           BTU/HR                 -0.22576E+07


BLOCK:  B1      MODEL: MIXER
-----------------------------
 INLET STREAMS:       VENT1      VENT2
 OUTLET STREAM:       CMBVENT
 PROPERTY OPTION SET:  POLYNRTL  POLYMER NRTL / REDLICH-KWONG

            ***  MASS AND ENERGY BALANCE  ***
                      IN           OUT       RELATIVE DIFF.
  TOTAL BALANCE
    MOLE(LBMOL/HR)        195.668       195.668       0.00000
    MASS(LB/HR   )        3559.79       3559.79       0.127746E-15
```

```
   ENTHALPY(BTU/HR  )      -0.198638E+08   -0.198638E+08    0.187542E-15

               ***  CO2 EQUIVALENT SUMMARY ***
  FEED STREAMS CO2E            0.00000      LB/HR
  PRODUCT STREAMS CO2E         0.00000      LB/HR
  NET STREAMS CO2E PRODUCTION   0.00000      LB/HR
  UTILITIES CO2E PRODUCTION     0.00000      LB/HR
  TOTAL CO2E PRODUCTION        0.00000      LB/HR

                 ***  INPUT DATA  ***
 TWO    PHASE      FLASH
 MAXIMUM NO. ITERATIONS                          30
 CONVERGENCE TOLERANCE                              0.000100000
 OUTLET PRESSURE:  MINIMUM OF INLET STREAM PRESSURES

BLOCK:  BATCH    MODEL: RBATCH
------------------------------
 INLET STREAM:          FEED
 OUTLET STREAMS:        OLIG       VENT1
 PROPERTY OPTION SET:   POLYNRTL  POLYMER NRTL / REDLICH-KWONG

               ***  MASS AND ENERGY BALANCE  ***
                     IN          OUT       GENERATION   RELATIVE DIFF.
 TOTAL BALANCE
 MOLE(LBMOL/HR)        196.539       240.700       44.1609     -0.236159E-15
 MASS(LB/HR   )        13809.8       13809.7                   0.999999E-06
 ENTHALPY(BTU/HR  )   -0.320444E+08 -0.249738E+08              -0.220649

               ***  CO2 EQUIVALENT SUMMARY ***
  FEED STREAMS CO2E            0.00000      LB/HR
  PRODUCT STREAMS CO2E         0.00000      LB/HR
  NET STREAMS CO2E PRODUCTION   0.00000      LB/HR
  UTILITIES CO2E PRODUCTION     0.00000      LB/HR
  TOTAL CO2E PRODUCTION        0.00000      LB/HR


                 ***  INPUT DATA  ***

 REACTOR TYPE:         CONSTANT  TEMPERATURE
                 2 PHASE: RXN IN LIQUID PHASE
                 DO FLASH CALCULATIONS AT EACH TIME STEP
 REACTOR DOWNTIME      HR                          0.10000E-05
 FEED-TIME             HR                     1.0000
 SET POINT TEMPERATURE F                           518.00
```

INTEGRATION TOLERANCE 0.10000E-03
INTEGRATION METHOD GEAR
CORRECTOR METHOD NEWTON
VENT ALGORITHM OLD

GAIN TERM FOR CONTROLLER 2500.0
INT-TIME TERM FOR CONTROLLER 0.10000E+36
DER-TIME TERM FOR CONTROLLER 0.0000

STOP CRITERIA

CRITERION 1 : REACTOR TIME
REACHES 1.0000 HR FROM-BELOW

MAXIMUM TIME HR 5.0000

*** RESULTS ***

STOP CRITERION SATISFIED 1
REACTION TIME HR 1.0000
REACTOR HEAT LOAD PER CYCLE BTU 0.72636E+06
AVERAGE HEAT DUTY OVER CYCLE BTU/HR 0.72635E+06
REACTOR MINIMUM TEMPERATURE F 351.61
REACTOR MAXIMUM TEMPERATURE F 518.17

***** RESULTS PROFILES *****

** OVERALL REACTOR CONTENTS **

TIME HR	PRESSURE PSIA	TEMPERATURE F	INST. DUTY BTU/HR
0.0000	121.24	395.34	0.35882E+10
0.16667E-01	121.24	518.13	-0.29338E+07
0.33333E-01	121.24	518.15	-0.35438E+07
0.50000E-01	121.24	518.17	-0.37924E+07
0.66667E-01	121.24	518.17	-0.38302E+07
0.83333E-01	121.24	518.17	-0.38367E+07
0.10000	121.24	518.17	-0.38490E+07

0.11667	121.24	518.17	-0.38521E+07
0.13333	121.24	518.17	-0.38521E+07
0.15000	121.24	518.17	-0.38521E+07
0.16667	121.24	518.17	-0.38521E+07
0.18333	121.24	518.17	-0.38521E+07
0.20000	121.24	518.17	-0.38521E+07
0.21667	121.24	518.17	-0.38521E+07
0.23333	121.24	518.17	-0.38521E+07
0.25000	121.24	518.17	-0.38521E+07
0.26667	121.24	518.17	-0.38521E+07
0.28333	121.24	518.17	-0.38521E+07
0.30000	121.24	518.17	-0.38521E+07
0.31667	121.24	518.17	-0.38521E+07
0.33333	121.24	518.17	-0.38521E+07
0.35000	121.24	518.17	-0.38521E+07
0.36667	121.24	518.17	-0.38521E+07
0.38333	121.24	518.17	-0.38521E+07
0.40000	121.24	518.17	-0.38521E+07
0.41667	121.24	518.17	-0.38521E+07
0.43333	121.24	518.17	-0.38521E+07
0.45000	121.24	518.17	-0.38521E+07
0.46667	121.24	518.17	-0.38521E+07
0.48333	121.24	518.17	-0.38521E+07
0.50000	121.24	518.17	-0.38521E+07
0.51667	121.24	518.17	-0.38521E+07
0.53333	121.24	518.17	-0.38521E+07
0.55000	121.24	518.17	-0.38521E+07
0.56667	121.24	518.17	-0.38521E+07
0.58333	121.24	518.17	-0.38521E+07
0.60000	121.24	518.17	-0.38521E+07
0.61667	121.24	518.17	-0.38521E+07
0.63333	121.24	518.17	-0.38521E+07
0.65000	121.24	518.17	-0.38521E+07
0.66667	121.24	518.17	-0.38521E+07
0.68333	121.24	518.17	-0.38521E+07
0.70000	121.24	518.17	-0.38521E+07
0.71667	121.24	518.17	-0.38521E+07
0.73333	121.24	518.17	-0.38521E+07
0.75000	121.24	518.17	-0.38521E+07
0.76667	121.24	518.17	-0.38521E+07
0.78333	121.24	518.17	-0.38521E+07
0.80000	121.24	518.17	-0.38521E+07
0.81667	121.24	518.17	-0.38521E+07
0.83333	121.24	518.17	-0.38521E+07

0.85000	121.24	518.17	-0.38521E+07
0.86667	121.24	518.17	-0.38521E+07
0.88333	121.24	518.17	-0.38521E+07
0.90000	121.24	518.17	-0.38521E+07
0.91667	121.24	518.17	-0.38521E+07
0.93333	121.24	518.17	-0.38521E+07
0.95000	121.24	518.17	-0.38521E+07
0.96667	121.24	518.17	-0.38521E+07
0.98333	121.24	518.17	-0.38521E+07
1.0000	121.24	518.17	-0.38521E+07
1.0000	121.24	518.17	-0.38521E+07

TIME HR	REACTION MASS LB
0.0000	13609.
0.16667E-01	10379.
0.33333E-01	10379.
0.50000E-01	10379.
0.66667E-01	10379.
0.83333E-01	10379.
0.10000	10379.
0.11667	10379.
0.13333	10379.
0.15000	10379.
0.16667	10379.
0.18333	10379.
0.20000	10379.
0.21667	10379.
0.23333	10379.
0.25000	10379.
0.26667	10379.
0.28333	10379.
0.30000	10379.
0.31667	10379.
0.33333	10379.
0.35000	10379.
0.36667	10379.
0.38333	10379.
0.40000	10379.
0.41667	10379.
0.43333	10379.
0.45000	10379.

0.46667	10379.
0.48333	10379.
0.50000	10379.
0.51667	10379.
0.53333	10379.
0.55000	10379.
0.56667	10379.
0.58333	10379.
0.60000	10379.
0.61667	10379.
0.63333	10379.
0.65000	10379.
0.66667	10379.
0.68333	10379.
0.70000	10379.
0.71667	10379.
0.73333	10379.
0.75000	10379.
0.76667	10379.
0.78333	10379.
0.80000	10379.
0.81667	10379.
0.83333	10379.
0.85000	10379.
0.86667	10379.
0.88333	10379.
0.90000	10379.
0.91667	10379.
0.93333	10379.
0.95000	10379.
0.96667	10379.
0.98333	10379.
1.0000	10379.
1.0000	10379.

***** RESULTS PROFILES *****

** RESULTS BY SUBSTREAMS **

SUBSTREAM: MIXED

TIME HR	PRESSURE PSIA	TEMPERATURE F	VAPOR FRAC
0.0000	121.24	395.34	0.48697E-09
0.16667E-01	121.24	518.13	0.10429E-05
0.33333E-01	121.24	518.15	0.0000
0.50000E-01	121.24	518.17	0.0000
0.66667E-01	121.24	518.17	0.0000
0.83333E-01	121.24	518.17	0.0000
0.10000	121.24	518.17	0.0000
0.11667	121.24	518.17	0.0000
0.13333	121.24	518.17	0.0000
0.15000	121.24	518.17	0.0000
0.16667	121.24	518.17	0.0000
0.18333	121.24	518.17	0.0000
0.20000	121.24	518.17	0.0000
0.21667	121.24	518.17	0.0000
0.23333	121.24	518.17	0.0000
0.25000	121.24	518.17	0.0000
0.26667	121.24	518.17	0.0000
0.28333	121.24	518.17	0.0000
0.30000	121.24	518.17	0.0000
0.31667	121.24	518.17	0.0000
0.33333	121.24	518.17	0.0000
0.35000	121.24	518.17	0.0000
0.36667	121.24	518.17	0.0000
0.38333	121.24	518.17	0.0000
0.40000	121.24	518.17	0.0000
0.41667	121.24	518.17	0.0000
0.43333	121.24	518.17	0.0000
0.45000	121.24	518.17	0.0000
0.46667	121.24	518.17	0.0000
0.48333	121.24	518.17	0.0000
0.50000	121.24	518.17	0.0000
0.51667	121.24	518.17	0.0000
0.53333	121.24	518.17	0.0000
0.55000	121.24	518.17	0.0000
0.56667	121.24	518.17	0.0000
0.58333	121.24	518.17	0.0000
0.60000	121.24	518.17	0.0000
0.61667	121.24	518.17	0.0000
0.63333	121.24	518.17	0.0000
0.65000	121.24	518.17	0.0000

0.66667	121.24	518.17	0.0000
0.68333	121.24	518.17	0.0000
0.70000	121.24	518.17	0.0000
0.71667	121.24	518.17	0.0000
0.73333	121.24	518.17	0.0000
0.75000	121.24	518.17	0.0000
0.76667	121.24	518.17	0.0000
0.78333	121.24	518.17	0.0000
0.80000	121.24	518.17	0.0000
0.81667	121.24	518.17	0.0000
0.83333	121.24	518.17	0.0000
0.85000	121.24	518.17	0.0000
0.86667	121.24	518.17	0.0000
0.88333	121.24	518.17	0.0000
0.90000	121.24	518.17	0.0000
0.91667	121.24	518.17	0.0000
0.93333	121.24	518.17	0.0000
0.95000	121.24	518.17	0.0000
0.96667	121.24	518.17	0.0000
0.98333	121.24	518.17	0.0000
1.0000	121.24	518.17	0.0000
1.0000	121.24	518.17	0.0000

** COMPONENT ATTRIBUTE PROFILES **

SUBSTREAM: MIXED

TIME HR	NYLON-01 SFRAC E-ADA	NYLON-01 SFRAC R-ADA	NYLON-01 SFRAC E-HDMA	NYLON-01 SFRAC R-HDMA
0.0000	0.0000	0.0000	0.0000	0.0000
0.16667E-01	0.16325E-01	0.48552	0.89473E-02	0.48921
0.33333E-01	0.16323E-01	0.48552	0.89451E-02	0.48921
0.50000E-01	0.16323E-01	0.48552	0.89450E-02	0.48921
0.66667E-01	0.16323E-01	0.48552	0.89450E-02	0.48921
0.83333E-01	0.16323E-01	0.48552	0.89450E-02	0.48921
0.10000	0.16323E-01	0.48552	0.89450E-02	0.48921
0.11667	0.16323E-01	0.48552	0.89450E-02	0.48921
0.13333	0.16323E-01	0.48552	0.89450E-02	0.48921
0.15000	0.16323E-01	0.48552	0.89450E-02	0.48921
0.16667	0.16323E-01	0.48552	0.89450E-02	0.48921
0.18333	0.16323E-01	0.48552	0.89450E-02	0.48921

0.20000	0.16323E-01	0.48552	0.89450E-02	0.48921
0.21667	0.16323E-01	0.48552	0.89450E-02	0.48921
0.23333	0.16323E-01	0.48552	0.89450E-02	0.48921
0.25000	0.16323E-01	0.48552	0.89450E-02	0.48921
0.26667	0.16323E-01	0.48552	0.89450E-02	0.48921
0.28333	0.16323E-01	0.48552	0.89450E-02	0.48921
0.30000	0.16323E-01	0.48552	0.89450E-02	0.48921
0.31667	0.16323E-01	0.48552	0.89450E-02	0.48921
0.33333	0.16323E-01	0.48552	0.89450E-02	0.48921
0.35000	0.16323E-01	0.48552	0.89450E-02	0.48921
0.36667	0.16323E-01	0.48552	0.89450E-02	0.48921
0.38333	0.16323E-01	0.48552	0.89450E-02	0.48921
0.40000	0.16323E-01	0.48552	0.89450E-02	0.48921
0.41667	0.16323E-01	0.48552	0.89450E-02	0.48921
0.43333	0.16323E-01	0.48552	0.89450E-02	0.48921
0.45000	0.16323E-01	0.48552	0.89450E-02	0.48921
0.46667	0.16323E-01	0.48552	0.89450E-02	0.48921
0.48333	0.16323E-01	0.48552	0.89450E-02	0.48921
0.50000	0.16323E-01	0.48552	0.89450E-02	0.48921
0.51667	0.16323E-01	0.48552	0.89450E-02	0.48921
0.53333	0.16323E-01	0.48552	0.89450E-02	0.48921
0.55000	0.16323E-01	0.48552	0.89450E-02	0.48921
0.56667	0.16323E-01	0.48552	0.89450E-02	0.48921
0.58333	0.16323E-01	0.48552	0.89450E-02	0.48921
0.60000	0.16323E-01	0.48552	0.89450E-02	0.48921
0.61667	0.16323E-01	0.48552	0.89450E-02	0.48921
0.63333	0.16323E-01	0.48552	0.89450E-02	0.48921
0.65000	0.16323E-01	0.48552	0.89450E-02	0.48921
0.66667	0.16323E-01	0.48552	0.89450E-02	0.48921
0.68333	0.16323E-01	0.48552	0.89450E-02	0.48921
0.70000	0.16323E-01	0.48552	0.89450E-02	0.48921
0.71667	0.16323E-01	0.48552	0.89450E-02	0.48921
0.73333	0.16323E-01	0.48552	0.89450E-02	0.48921
0.75000	0.16323E-01	0.48552	0.89450E-02	0.48921
0.76667	0.16323E-01	0.48552	0.89450E-02	0.48921
0.78333	0.16323E-01	0.48552	0.89450E-02	0.48921
0.80000	0.16323E-01	0.48552	0.89450E-02	0.48921
0.81667	0.16323E-01	0.48552	0.89450E-02	0.48921
0.83333	0.16323E-01	0.48552	0.89450E-02	0.48921
0.85000	0.16323E-01	0.48552	0.89450E-02	0.48921
0.86667	0.16323E-01	0.48552	0.89450E-02	0.48921
0.88333	0.16323E-01	0.48552	0.89450E-02	0.48921
0.90000	0.16323E-01	0.48552	0.89450E-02	0.48921
0.91667	0.16323E-01	0.48552	0.89450E-02	0.48921

0.93333	0.16323E-01	0.48552	0.89450E-02	0.48921
0.95000	0.16323E-01	0.48552	0.89450E-02	0.48921
0.96667	0.16323E-01	0.48552	0.89450E-02	0.48921
0.98333	0.16323E-01	0.48552	0.89450E-02	0.48921
1.0000	0.16323E-01	0.48552	0.89450E-02	0.48921
1.0000	0.16323E-01	0.48552	0.89450E-02	0.48921

** COMPONENT ATTRIBUTE PROFILES **

SUBSTREAM: MIXED

TIME HR	NYLON-01 SFLOW E-ADA	NYLON-01 SFLOW R-ADA	NYLON-01 SFLOW E-HDMA	NYLON-01 SFLOW R-HDMA
0.0000	0.0000	0.0000	0.0000	0.0000
0.16667E-01	0.66927	19.904	0.36680	20.055
0.33333E-01	0.66919	19.904	0.36671	20.056
0.50000E-01	0.66918	19.904	0.36671	20.056
0.66667E-01	0.66918	19.904	0.36671	20.056
0.83333E-01	0.66918	19.904	0.36671	20.056
0.10000	0.66918	19.904	0.36671	20.056
0.11667	0.66918	19.904	0.36671	20.056
0.13333	0.66918	19.904	0.36671	20.056
0.15000	0.66918	19.904	0.36671	20.056
0.16667	0.66918	19.904	0.36671	20.056
0.18333	0.66918	19.904	0.36671	20.056
0.20000	0.66918	19.904	0.36671	20.056
0.21667	0.66918	19.904	0.36671	20.056
0.23333	0.66918	19.904	0.36671	20.056
0.25000	0.66918	19.904	0.36671	20.056
0.26667	0.66918	19.904	0.36671	20.056
0.28333	0.66918	19.904	0.36671	20.056
0.30000	0.66918	19.904	0.36671	20.056
0.31667	0.66918	19.904	0.36671	20.056
0.33333	0.66918	19.904	0.36671	20.056
0.35000	0.66918	19.904	0.36671	20.056
0.36667	0.66918	19.904	0.36671	20.056
0.38333	0.66918	19.904	0.36671	20.056
0.40000	0.66918	19.904	0.36671	20.056
0.41667	0.66918	19.904	0.36671	20.056
0.43333	0.66918	19.904	0.36671	20.056
0.45000	0.66918	19.904	0.36671	20.056

0.46667	0.66918	19.904	0.36671	20.056
0.48333	0.66918	19.904	0.36671	20.056
0.50000	0.66918	19.904	0.36671	20.056
0.51667	0.66918	19.904	0.36671	20.056
0.53333	0.66918	19.904	0.36671	20.056
0.55000	0.66918	19.904	0.36671	20.056
0.56667	0.66918	19.904	0.36671	20.056
0.58333	0.66918	19.904	0.36671	20.056
0.60000	0.66918	19.904	0.36671	20.056
0.61667	0.66918	19.904	0.36671	20.056
0.63333	0.66918	19.904	0.36671	20.056
0.65000	0.66918	19.904	0.36671	20.056
0.66667	0.66918	19.904	0.36671	20.056
0.68333	0.66918	19.904	0.36671	20.056
0.70000	0.66918	19.904	0.36671	20.056
0.71667	0.66918	19.904	0.36671	20.056
0.73333	0.66918	19.904	0.36671	20.056
0.75000	0.66918	19.904	0.36671	20.056
0.76667	0.66918	19.904	0.36671	20.056
0.78333	0.66918	19.904	0.36671	20.056
0.80000	0.66918	19.904	0.36671	20.056
0.81667	0.66918	19.904	0.36671	20.056
0.83333	0.66918	19.904	0.36671	20.056
0.85000	0.66918	19.904	0.36671	20.056
0.86667	0.66918	19.904	0.36671	20.056
0.88333	0.66918	19.904	0.36671	20.056
0.90000	0.66918	19.904	0.36671	20.056
0.91667	0.66918	19.904	0.36671	20.056
0.93333	0.66918	19.904	0.36671	20.056
0.95000	0.66918	19.904	0.36671	20.056
0.96667	0.66918	19.904	0.36671	20.056
0.98333	0.66918	19.904	0.36671	20.056
1.0000	0.66918	19.904	0.36671	20.056
1.0000	0.66918	19.904	0.36671	20.056

** COMPONENT ATTRIBUTE PROFILES **

SUBSTREAM: MIXED

TIME	NYLON-01	NYLON-01	NYLON-01	NYLON-01
HR	EFRAC	EFRAC	ZMOM	FMOM
	E-ADA	E-HDMA	ZMOM	FMOM

0.0000	0.0000	0.0000	0.0000	0.0000
0.16667E-01	0.64597	0.35403	0.51804	40.996
0.33333E-01	0.64600	0.35400	0.51795	40.996
0.50000E-01	0.64600	0.35400	0.51795	40.996
0.66667E-01	0.64600	0.35400	0.51794	40.996
0.83333E-01	0.64600	0.35400	0.51794	40.996
0.10000	0.64600	0.35400	0.51794	40.996
0.11667	0.64600	0.35400	0.51794	40.996
0.13333	0.64600	0.35400	0.51794	40.996
0.15000	0.64600	0.35400	0.51794	40.996
0.16667	0.64600	0.35400	0.51794	40.996
0.18333	0.64600	0.35400	0.51794	40.996
0.20000	0.64600	0.35400	0.51794	40.996
0.21667	0.64600	0.35400	0.51794	40.996
0.23333	0.64600	0.35400	0.51794	40.996
0.25000	0.64600	0.35400	0.51794	40.996
0.26667	0.64600	0.35400	0.51794	40.996
0.28333	0.64600	0.35400	0.51794	40.996
0.30000	0.64600	0.35400	0.51794	40.996
0.31667	0.64600	0.35400	0.51794	40.996
0.33333	0.64600	0.35400	0.51794	40.996
0.35000	0.64600	0.35400	0.51794	40.996
0.36667	0.64600	0.35400	0.51794	40.996
0.38333	0.64600	0.35400	0.51794	40.996
0.40000	0.64600	0.35400	0.51794	40.996
0.41667	0.64600	0.35400	0.51794	40.996
0.43333	0.64600	0.35400	0.51794	40.996
0.45000	0.64600	0.35400	0.51794	40.996
0.46667	0.64600	0.35400	0.51794	40.996
0.48333	0.64600	0.35400	0.51794	40.996
0.50000	0.64600	0.35400	0.51794	40.996
0.51667	0.64600	0.35400	0.51794	40.996
0.53333	0.64600	0.35400	0.51794	40.996
0.55000	0.64600	0.35400	0.51794	40.996
0.56667	0.64600	0.35400	0.51794	40.996
0.58333	0.64600	0.35400	0.51794	40.996
0.60000	0.64600	0.35400	0.51794	40.996
0.61667	0.64600	0.35400	0.51794	40.996
0.63333	0.64600	0.35400	0.51794	40.996
0.65000	0.64600	0.35400	0.51794	40.996
0.66667	0.64600	0.35400	0.51794	40.996
0.68333	0.64600	0.35400	0.51794	40.996
0.70000	0.64600	0.35400	0.51794	40.996
0.71667	0.64600	0.35400	0.51794	40.996

0.73333	0.64600	0.35400	0.51794	40.996
0.75000	0.64600	0.35400	0.51794	40.996
0.76667	0.64600	0.35400	0.51794	40.996
0.78333	0.64600	0.35400	0.51794	40.996
0.80000	0.64600	0.35400	0.51794	40.996
0.81667	0.64600	0.35400	0.51794	40.996
0.83333	0.64600	0.35400	0.51794	40.996
0.85000	0.64600	0.35400	0.51794	40.996
0.86667	0.64600	0.35400	0.51794	40.996
0.88333	0.64600	0.35400	0.51794	40.996
0.90000	0.64600	0.35400	0.51794	40.996
0.91667	0.64600	0.35400	0.51794	40.996
0.93333	0.64600	0.35400	0.51794	40.996
0.95000	0.64600	0.35400	0.51794	40.996
0.96667	0.64600	0.35400	0.51794	40.996
0.98333	0.64600	0.35400	0.51794	40.996
1.0000	0.64600	0.35400	0.51794	40.996
1.0000	0.64600	0.35400	0.51794	40.996

** COMPONENT ATTRIBUTE PROFILES **

SUBSTREAM: MIXED

TIME HR	NYLON-01 DPN DPN	NYLON-01 MWN MWN
0.0000	0.0000	0.0000
0.16667E-01	79.136	8977.4
0.33333E-01	79.150	8979.0
0.50000E-01	79.151	8979.0
0.66667E-01	79.151	8979.1
0.83333E-01	79.151	8979.1
0.10000	79.151	8979.1
0.11667	79.151	8979.1
0.13333	79.151	8979.1
0.15000	79.151	8979.1
0.16667	79.151	8979.1
0.18333	79.151	8979.1
0.20000	79.151	8979.1
0.21667	79.151	8979.1
0.23333	79.151	8979.1
0.25000	79.151	8979.1

0.26667	79.151	8979.1
0.28333	79.151	8979.1
0.30000	79.151	8979.1
0.31667	79.151	8979.1
0.33333	79.151	8979.1
0.35000	79.151	8979.1
0.36667	79.151	8979.1
0.38333	79.151	8979.1
0.40000	79.151	8979.1
0.41667	79.151	8979.1
0.43333	79.151	8979.1
0.45000	79.151	8979.1
0.46667	79.151	8979.1
0.48333	79.151	8979.1
0.50000	79.151	8979.1
0.51667	79.151	8979.1
0.53333	79.151	8979.1
0.55000	79.151	8979.1
0.56667	79.151	8979.1
0.58333	79.151	8979.1
0.60000	79.151	8979.1
0.61667	79.151	8979.1
0.63333	79.151	8979.1
0.65000	79.151	8979.1
0.66667	79.151	8979.1
0.68333	79.151	8979.1
0.70000	79.151	8979.1
0.71667	79.151	8979.1
0.73333	79.151	8979.1
0.75000	79.151	8979.1
0.76667	79.151	8979.1
0.78333	79.151	8979.1
0.80000	79.151	8979.1
0.81667	79.151	8979.1
0.83333	79.151	8979.1
0.85000	79.151	8979.1
0.86667	79.151	8979.1
0.88333	79.151	8979.1
0.90000	79.151	8979.1
0.91667	79.151	8979.1
0.93333	79.151	8979.1
0.95000	79.151	8979.1
0.96667	79.151	8979.1
0.98333	79.151	8979.1

1.0000	79.151	8979.1
1.0000	79.151	8979.1

** COMPONENT MASS AMOUNTS **

SUBSTREAM: MIXED

TIME HR	NYLON-01 LB	ADA LB	HDMA LB	WATER LB
0.0000	0.0000	6630.4	5234.6	1743.5
0.16667E-01	10253.	1.8127	0.42967	123.58
0.33333E-01	10253.	1.8122	0.42946	123.54
0.50000E-01	10253.	1.8122	0.42945	123.53
0.66667E-01	10253.	1.8121	0.42945	123.53
0.83333E-01	10253.	1.8121	0.42945	123.53
0.10000	10253.	1.8121	0.42945	123.53
0.11667	10253.	1.8121	0.42945	123.53
0.13333	10253.	1.8121	0.42945	123.53
0.15000	10253.	1.8121	0.42945	123.53
0.16667	10253.	1.8121	0.42945	123.53
0.18333	10253.	1.8121	0.42945	123.53
0.20000	10253.	1.8121	0.42945	123.53
0.21667	10253.	1.8121	0.42945	123.53
0.23333	10253.	1.8121	0.42945	123.53
0.25000	10253.	1.8121	0.42945	123.53
0.26667	10253.	1.8121	0.42945	123.53
0.28333	10253.	1.8121	0.42945	123.53
0.30000	10253.	1.8121	0.42945	123.53
0.31667	10253.	1.8121	0.42945	123.53
0.33333	10253.	1.8121	0.42945	123.53
0.35000	10253.	1.8121	0.42945	123.53
0.36667	10253.	1.8121	0.42945	123.53
0.38333	10253.	1.8121	0.42945	123.53
0.40000	10253.	1.8121	0.42945	123.53
0.41667	10253.	1.8121	0.42945	123.53
0.43333	10253.	1.8121	0.42945	123.53
0.45000	10253.	1.8121	0.42945	123.53
0.46667	10253.	1.8121	0.42945	123.53
0.48333	10253.	1.8121	0.42945	123.53
0.50000	10253.	1.8121	0.42945	123.53
0.51667	10253.	1.8121	0.42945	123.53

0.53333	10253.	1.8121	0.42945	123.53
0.55000	10253.	1.8121	0.42945	123.53
0.56667	10253.	1.8121	0.42945	123.53
0.58333	10253.	1.8121	0.42945	123.53
0.60000	10253.	1.8121	0.42945	123.53
0.61667	10253.	1.8121	0.42945	123.53
0.63333	10253.	1.8121	0.42945	123.53
0.65000	10253.	1.8121	0.42945	123.53
0.66667	10253.	1.8121	0.42945	123.53
0.68333	10253.	1.8121	0.42945	123.53
0.70000	10253.	1.8121	0.42945	123.53
0.71667	10253.	1.8121	0.42945	123.53
0.73333	10253.	1.8121	0.42945	123.53
0.75000	10253.	1.8121	0.42945	123.53
0.76667	10253.	1.8121	0.42945	123.53
0.78333	10253.	1.8121	0.42945	123.53
0.80000	10253.	1.8121	0.42945	123.53
0.81667	10253.	1.8121	0.42945	123.53
0.83333	10253.	1.8121	0.42945	123.53
0.85000	10253.	1.8121	0.42945	123.53
0.86667	10253.	1.8121	0.42945	123.53
0.88333	10253.	1.8121	0.42945	123.53
0.90000	10253.	1.8121	0.42945	123.53
0.91667	10253.	1.8121	0.42945	123.53
0.93333	10253.	1.8121	0.42945	123.53
0.95000	10253.	1.8121	0.42945	123.53
0.96667	10253.	1.8121	0.42945	123.53
0.98333	10253.	1.8121	0.42945	123.53
1.0000	10253.	1.8121	0.42945	123.53
1.0000	10253.	1.8121	0.42945	123.53

** RESULTS BY SUBSTREAMS **

** COMPONENT MOLE FRACTIONS **

COMPONENT MOLE FRACTIONS

SUBSTREAM: MIXED

TIME HR	NYLON-01	ADA	HDMA	WATER

0.0000	0.0000	0.24237	0.24064	0.51700
0.16667E-01	0.86823	0.23771E-03	0.70862E-04	0.13146
0.33333E-01	0.86827	0.23765E-03	0.70829E-04	0.13142
0.50000E-01	0.86827	0.23765E-03	0.70828E-04	0.13142
0.66667E-01	0.86827	0.23765E-03	0.70828E-04	0.13142
0.83333E-01	0.86827	0.23765E-03	0.70828E-04	0.13142
0.10000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.11667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.13333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.15000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.16667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.18333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.20000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.21667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.23333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.25000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.26667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.28333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.30000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.31667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.33333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.35000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.36667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.38333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.40000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.41667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.43333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.45000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.46667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.48333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.50000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.51667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.53333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.55000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.56667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.58333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.60000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.61667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.63333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.65000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.66667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.68333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.70000	0.86827	0.23765E-03	0.70828E-04	0.13142

0.71667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.73333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.75000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.76667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.78333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.80000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.81667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.83333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.85000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.86667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.88333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.90000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.91667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.93333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.95000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.96667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.98333	0.86827	0.23765E-03	0.70828E-04	0.13142
1.0000	0.86827	0.23765E-03	0.70828E-04	0.13142
1.0000	0.86827	0.23765E-03	0.70828E-04	0.13142

** RESULTS BY SUBSTREAMS **

** LIQUID PHASE MOLE FRACTIONS **

COMPONENT MOLE FRACTIONS

SUBSTREAM: MIXED LIQUID

TIME HR	NYLON-01	ADA	HDMA	WATER
0.0000	0.0000	0.24237	0.24064	0.51700
0.16667E-01	0.86823	0.23771E-03	0.70862E-04	0.13146
0.33333E-01	0.86827	0.23765E-03	0.70829E-04	0.13142
0.50000E-01	0.86827	0.23765E-03	0.70828E-04	0.13142
0.66667E-01	0.86827	0.23765E-03	0.70828E-04	0.13142
0.83333E-01	0.86827	0.23765E-03	0.70828E-04	0.13142
0.10000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.11667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.13333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.15000	0.86827	0.23765E-03	0.70828E-04	0.13142

0.16667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.18333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.20000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.21667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.23333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.25000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.26667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.28333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.30000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.31667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.33333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.35000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.36667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.38333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.40000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.41667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.43333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.45000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.46667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.48333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.50000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.51667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.53333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.55000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.56667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.58333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.60000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.61667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.63333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.65000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.66667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.68333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.70000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.71667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.73333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.75000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.76667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.78333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.80000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.81667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.83333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.85000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.86667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.88333	0.86827	0.23765E-03	0.70828E-04	0.13142

0.90000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.91667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.93333	0.86827	0.23765E-03	0.70828E-04	0.13142
0.95000	0.86827	0.23765E-03	0.70828E-04	0.13142
0.96667	0.86827	0.23765E-03	0.70828E-04	0.13142
0.98333	0.86827	0.23765E-03	0.70828E-04	0.13142
1.0000	0.86827	0.23765E-03	0.70828E-04	0.13142
1.0000	0.86827	0.23765E-03	0.70828E-04	0.13142

** RESULTS BY SUBSTREAMS **

** VAPOR PHASE MOLE FRACTIONS **

COMPONENT MOLE FRACTIONS

SUBSTREAM: MIXED VAPOR

TIME HR	NYLON-01	ADA	HDMA	WATER
0.0000	0.0000	0.36292E-03	0.35327E-01	0.96431
0.16667E-01	0.99604E-82	0.72217E-05	0.56084E-04	0.99994
0.33333E-01				
0.50000E-01				
0.66667E-01				
0.83333E-01				
0.10000				
0.11667				
0.13333				
0.15000				
0.16667				
0.18333				
0.20000				
0.21667				
0.23333				
0.25000				
0.26667				
0.28333				
0.30000				
0.31667				
0.33333				

0.35000
0.36667
0.38333
0.40000
0.41667
0.43333
0.45000
0.46667
0.48333
0.50000
0.51667
0.53333
0.55000
0.56667
0.58333
0.60000
0.61667
0.63333
0.65000
0.66667
0.68333
0.70000
0.71667
0.73333
0.75000
0.76667
0.78333
0.80000
0.81667
0.83333
0.85000
0.86667
0.88333
0.90000
0.91667
0.93333
0.95000
0.96667
0.98333
1.0000
1.0000

** VENT ACCUMULATOR PROFILES **

TIME HR	PRESSURE PSIA	TEMPERATURE F	VAPOR FRAC
0.0000	121.24	395.34	1.0000
0.16667E-01	121.24	373.82	1.0000
0.33333E-01	121.24	373.83	1.0000
0.50000E-01	121.24	373.83	1.0000
0.66667E-01	121.24	373.83	1.0000
0.83333E-01	121.24	373.83	1.0000
0.10000	121.24	373.83	1.0000
0.11667	121.24	373.83	1.0000
0.13333	121.24	373.83	1.0000
0.15000	121.24	373.83	1.0000
0.16667	121.24	373.83	1.0000
0.18333	121.24	373.83	1.0000
0.20000	121.24	373.83	1.0000
0.21667	121.24	373.83	1.0000
0.23333	121.24	373.83	1.0000
0.25000	121.24	373.83	1.0000
0.26667	121.24	373.83	1.0000
0.28333	121.24	373.83	1.0000
0.30000	121.24	373.83	1.0000
0.31667	121.24	373.83	1.0000
0.33333	121.24	373.83	1.0000
0.35000	121.24	373.83	1.0000
0.36667	121.24	373.83	1.0000
0.38333	121.24	373.83	1.0000
0.40000	121.24	373.83	1.0000
0.41667	121.24	373.83	1.0000
0.43333	121.24	373.83	1.0000
0.45000	121.24	373.83	1.0000
0.46667	121.24	373.83	1.0000
0.48333	121.24	373.83	1.0000
0.50000	121.24	373.83	1.0000
0.51667	121.24	373.83	1.0000
0.53333	121.24	373.83	1.0000
0.55000	121.24	373.83	1.0000
0.56667	121.24	373.83	1.0000
0.58333	121.24	373.83	1.0000
0.60000	121.24	373.83	1.0000

0.61667	121.24	373.83	1.0000
0.63333	121.24	373.83	1.0000
0.65000	121.24	373.83	1.0000
0.66667	121.24	373.83	1.0000
0.68333	121.24	373.83	1.0000
0.70000	121.24	373.83	1.0000
0.71667	121.24	373.83	1.0000
0.73333	121.24	373.83	1.0000
0.75000	121.24	373.83	1.0000
0.76667	121.24	373.83	1.0000
0.78333	121.24	373.83	1.0000
0.80000	121.24	373.83	1.0000
0.81667	121.24	373.83	1.0000
0.83333	121.24	373.83	1.0000
0.85000	121.24	373.83	1.0000
0.86667	121.24	373.83	1.0000
0.88333	121.24	373.83	1.0000
0.90000	121.24	373.83	1.0000
0.91667	121.24	373.83	1.0000
0.93333	121.24	373.83	1.0000
0.95000	121.24	373.83	1.0000
0.96667	121.24	373.83	1.0000
0.98333	121.24	373.83	1.0000
1.0000	121.24	373.83	1.0000
1.0000	121.24	373.83	1.0000

VENT ACCUMULATOR TOTAL MASS PROFILE

TIME HR	TOTAL MASS LB
0.0000	201.21
0.16667E-01	3431.0
0.33333E-01	3431.0
0.50000E-01	3431.1
0.66667E-01	3431.1
0.83333E-01	3431.1
0.10000	3431.1
0.11667	3431.1
0.13333	3431.1
0.15000	3431.1
0.16667	3431.1
0.18333	3431.1

0.20000	3431.1
0.21667	3431.1
0.23333	3431.1
0.25000	3431.1
0.26667	3431.1
0.28333	3431.1
0.30000	3431.1
0.31667	3431.1
0.33333	3431.1
0.35000	3431.1
0.36667	3431.1
0.38333	3431.1
0.40000	3431.1
0.41667	3431.1
0.43333	3431.1
0.45000	3431.1
0.46667	3431.1
0.48333	3431.1
0.50000	3431.1
0.51667	3431.1
0.53333	3431.1
0.55000	3431.1
0.56667	3431.1
0.58333	3431.1
0.60000	3431.1
0.61667	3431.1
0.63333	3431.1
0.65000	3431.1
0.66667	3431.1
0.68333	3431.1
0.70000	3431.1
0.71667	3431.1
0.73333	3431.1
0.75000	3431.1
0.76667	3431.1
0.78333	3431.1
0.80000	3431.1
0.81667	3431.1
0.83333	3431.1
0.85000	3431.1
0.86667	3431.1
0.88333	3431.1
0.90000	3431.1
0.91667	3431.1

0.93333	3431.1
0.95000	3431.1
0.96667	3431.1
0.98333	3431.1
1.0000	3431.1
1.0000	3431.1

VENT ACCUMULATOR MOLE FRACTION PROFILE

TIME HR	ADA	HDMA	WATER
0.0000	0.36292E-03	0.35327E-01	0.96431
0.16667E-01	0.19162E-04	0.18516E-02	0.99813
0.33333E-01	0.19162E-04	0.18515E-02	0.99813
0.50000E-01	0.19162E-04	0.18515E-02	0.99813
0.66667E-01	0.19162E-04	0.18515E-02	0.99813
0.83333E-01	0.19162E-04	0.18515E-02	0.99813
0.10000	0.19162E-04	0.18515E-02	0.99813
0.11667	0.19162E-04	0.18515E-02	0.99813
0.13333	0.19162E-04	0.18515E-02	0.99813
0.15000	0.19162E-04	0.18515E-02	0.99813
0.16667	0.19162E-04	0.18515E-02	0.99813
0.18333	0.19162E-04	0.18515E-02	0.99813
0.20000	0.19162E-04	0.18515E-02	0.99813
0.21667	0.19162E-04	0.18515E-02	0.99813
0.23333	0.19162E-04	0.18515E-02	0.99813
0.25000	0.19162E-04	0.18515E-02	0.99813
0.26667	0.19162E-04	0.18515E-02	0.99813
0.28333	0.19162E-04	0.18515E-02	0.99813
0.30000	0.19162E-04	0.18515E-02	0.99813
0.31667	0.19162E-04	0.18515E-02	0.99813
0.33333	0.19162E-04	0.18515E-02	0.99813
0.35000	0.19162E-04	0.18515E-02	0.99813
0.36667	0.19162E-04	0.18515E-02	0.99813
0.38333	0.19162E-04	0.18515E-02	0.99813
0.40000	0.19162E-04	0.18515E-02	0.99813
0.41667	0.19162E-04	0.18515E-02	0.99813
0.43333	0.19162E-04	0.18515E-02	0.99813
0.45000	0.19162E-04	0.18515E-02	0.99813
0.46667	0.19162E-04	0.18515E-02	0.99813
0.48333	0.19162E-04	0.18515E-02	0.99813
0.50000	0.19162E-04	0.18515E-02	0.99813

0.51667	0.19162E-04	0.18515E-02	0.99813
0.53333	0.19162E-04	0.18515E-02	0.99813
0.55000	0.19162E-04	0.18515E-02	0.99813
0.56667	0.19162E-04	0.18515E-02	0.99813
0.58333	0.19162E-04	0.18515E-02	0.99813
0.60000	0.19162E-04	0.18515E-02	0.99813
0.61667	0.19162E-04	0.18515E-02	0.99813
0.63333	0.19162E-04	0.18515E-02	0.99813
0.65000	0.19162E-04	0.18515E-02	0.99813
0.66667	0.19162E-04	0.18515E-02	0.99813
0.68333	0.19162E-04	0.18515E-02	0.99813
0.70000	0.19162E-04	0.18515E-02	0.99813
0.71667	0.19162E-04	0.18515E-02	0.99813
0.73333	0.19162E-04	0.18515E-02	0.99813
0.75000	0.19162E-04	0.18515E-02	0.99813
0.76667	0.19162E-04	0.18515E-02	0.99813
0.78333	0.19162E-04	0.18515E-02	0.99813
0.80000	0.19162E-04	0.18515E-02	0.99813
0.81667	0.19162E-04	0.18515E-02	0.99813
0.83333	0.19162E-04	0.18515E-02	0.99813
0.85000	0.19162E-04	0.18515E-02	0.99813
0.86667	0.19162E-04	0.18515E-02	0.99813
0.88333	0.19162E-04	0.18515E-02	0.99813
0.90000	0.19162E-04	0.18515E-02	0.99813
0.91667	0.19162E-04	0.18515E-02	0.99813
0.93333	0.19162E-04	0.18515E-02	0.99813
0.95000	0.19162E-04	0.18515E-02	0.99813
0.96667	0.19162E-04	0.18515E-02	0.99813
0.98333	0.19162E-04	0.18515E-02	0.99813
1.0000	0.19162E-04	0.18515E-02	0.99813
1.0000	0.19162E-04	0.18515E-02	0.99813

** VENT STREAM PROFILES **

TIME HR	PRESSURE PSIA	TEMPERATURE F	FLOWRATE LBMOL/HR
0.0000	121.24	395.34	0.0000
0.16667E-01	121.24	518.13	0.13846E-16
0.33333E-01	121.24	518.15	0.0000
0.50000E-01	121.24	518.17	0.0000

0.66667E-01	121.24	518.17	0.0000
0.83333E-01	121.24	518.17	0.0000
0.10000	121.24	518.17	0.0000
0.11667	121.24	518.17	0.0000
0.13333	121.24	518.17	0.0000
0.15000	121.24	518.17	0.0000
0.16667	121.24	518.17	0.0000
0.18333	121.24	518.17	0.0000
0.20000	121.24	518.17	0.0000
0.21667	121.24	518.17	0.0000
0.23333	121.24	518.17	0.0000
0.25000	121.24	518.17	0.0000
0.26667	121.24	518.17	0.0000
0.28333	121.24	518.17	0.0000
0.30000	121.24	518.17	0.0000
0.31667	121.24	518.17	0.0000
0.33333	121.24	518.17	0.0000
0.35000	121.24	518.17	0.0000
0.36667	121.24	518.17	0.0000
0.38333	121.24	518.17	0.0000
0.40000	121.24	518.17	0.0000
0.41667	121.24	518.17	0.0000
0.43333	121.24	518.17	0.0000
0.45000	121.24	518.17	0.0000
0.46667	121.24	518.17	0.0000
0.48333	121.24	518.17	0.0000
0.50000	121.24	518.17	0.0000
0.51667	121.24	518.17	0.0000
0.53333	121.24	518.17	0.0000
0.55000	121.24	518.17	0.0000
0.56667	121.24	518.17	0.0000
0.58333	121.24	518.17	0.0000
0.60000	121.24	518.17	0.0000
0.61667	121.24	518.17	0.0000
0.63333	121.24	518.17	0.0000
0.65000	121.24	518.17	0.0000
0.66667	121.24	518.17	0.0000
0.68333	121.24	518.17	0.0000
0.70000	121.24	518.17	0.0000
0.71667	121.24	518.17	0.0000
0.73333	121.24	518.17	0.0000
0.75000	121.24	518.17	0.0000
0.76667	121.24	518.17	0.0000
0.78333	121.24	518.17	0.0000

0.80000	121.24	518.17	0.0000
0.81667	121.24	518.17	0.0000
0.83333	121.24	518.17	0.0000
0.85000	121.24	518.17	0.0000
0.86667	121.24	518.17	0.0000
0.88333	121.24	518.17	0.0000
0.90000	121.24	518.17	0.0000
0.91667	121.24	518.17	0.0000
0.93333	121.24	518.17	0.0000
0.95000	121.24	518.17	0.0000
0.96667	121.24	518.17	0.0000
0.98333	121.24	518.17	0.0000
1.0000	121.24	518.17	0.0000
1.0000	121.24	518.17	0.0000

** VENT MOLE FRACTION PROFILE **

TIME HR	NYLON-01	ADA	HDMA	WATER
0.0000	0.0000	0.36292E-03	0.35327E-01	0.96431
0.16667E-01	0.99599E-82	0.72215E-05	0.56083E-04	0.99994
0.33333E-01	0.99658E-82	0.72241E-05	0.56082E-04	0.99994
0.50000E-01	0.99678E-82	0.72250E-05	0.56080E-04	0.99994
0.66667E-01	0.99678E-82	0.72251E-05	0.56079E-04	0.99994
0.83333E-01	0.99680E-82	0.72252E-05	0.56080E-04	0.99994
0.10000	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.11667	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.13333	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.15000	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.16667	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.18333	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.20000	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.21667	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.23333	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.25000	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.26667	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.28333	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.30000	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.31667	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.33333	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.35000	0.99682E-82	0.72252E-05	0.56080E-04	0.99994

0.36667	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.38333	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.40000	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.41667	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.43333	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.45000	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.46667	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.48333	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.50000	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.51667	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.53333	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.55000	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.56667	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.58333	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.60000	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.61667	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.63333	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.65000	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.66667	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.68333	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.70000	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.71667	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.73333	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.75000	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.76667	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.78333	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.80000	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.81667	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.83333	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.85000	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.86667	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.88333	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.90000	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.91667	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.93333	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.95000	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.96667	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
0.98333	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
1.0000	0.99682E-82	0.72252E-05	0.56080E-04	0.99994
1.0000	0.99682E-82	0.72252E-05	0.56080E-04	0.99994

BLOCK: C1   MODEL: HEATER

INLET STREAM: CMBVENT
OUTLET STREAM: WASTEH20
PROPERTY OPTION SET: POLYNRTL POLYMER NRTL / REDLICH-KWONG

*** MASS AND ENERGY BALANCE ***

	IN	OUT	RELATIVE DIFF.
TOTAL BALANCE			
MOLE(LBMOL/HR)	195.668	195.668	0.00000
MASS(LB/HR)	3559.79	3559.79	0.00000
ENTHALPY(BTU/HR)	-0.198638E+08	-0.239426E+08	0.170358

*** CO2 EQUIVALENT SUMMARY ***

FEED STREAMS CO2E	0.00000	LB/HR
PRODUCT STREAMS CO2E	0.00000	LB/HR
NET STREAMS CO2E PRODUCTION	0.00000	LB/HR
UTILITIES CO2E PRODUCTION	0.00000	LB/HR
TOTAL CO2E PRODUCTION	0.00000	LB/HR

*** INPUT DATA ***

TWO PHASE TP FLASH

SPECIFIED TEMPERATURE	F	100.0000
SPECIFIED PRESSURE	PSIA	14.7000
MAXIMUM NO. ITERATIONS		30
CONVERGENCE TOLERANCE		0.000100000

*** RESULTS ***

OUTLET TEMPERATURE	F	100.00
OUTLET PRESSURE	PSIA	14.700
HEAT DUTY	BTU/HR	-0.40788E+07
OUTLET VAPOR FRACTION		0.0000

V-L PHASE EQUILIBRIUM :

COMP	F(I)	X(I)	Y(I)	K(I)
ADA	0.19595E-04	0.19595E-04	0.25195E-11	0.83963E-08
HDMA	0.17847E-02	0.17847E-02	0.40152E-04	0.14692E-02
WATER	0.99820	0.99820	0.99996	0.65418E-01

BLOCK: CSTR2 MODEL: RCSTR

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 INLET STREAM:          OLIG
 OUTLET STREAMS:        LIQ-NY66    VENT2
 PROPERTY OPTION SET:   POLYNRTL  POLYMER NRTL / REDLICH-KWONG

                 ***  MASS AND ENERGY BALANCE  ***
                        IN          OUT       GENERATION   RELATIVE DIFF.
 TOTAL BALANCE
 MOLE(LBMOL/HR)         52.1762       52.8212      0.645011      0.134518E-15
 MASS(LB/HR   )        10378.7       10378.7                   0.175262E-15
 ENTHALPY(BTU/HR  )   -0.582687E+07 -0.572094E+07               -0.181800E-01

                 ***  CO2 EQUIVALENT SUMMARY ***
  FEED STREAMS CO2E            0.00000      LB/HR
  PRODUCT STREAMS CO2E         0.00000      LB/HR
  NET STREAMS CO2E PRODUCTION   0.00000      LB/HR
  UTILITIES CO2E PRODUCTION     0.00000      LB/HR
  TOTAL CO2E PRODUCTION         0.00000      LB/HR

                   ***  INPUT DATA  ***

  REACTOR TYPE: TEMP SPEC TWO     PHASE REACTOR

  RESIDENCE TIME                  HR                     0.50000E-01
  REACTOR TEMPERATURE             F                        518.00
  REACTOR PRESSURE                PSIA                    8.3326

                    ***  RESULTS  ***

  REACTOR HEAT DUTY               BTU/HR                  0.10593E+06
  REACTOR VOLUME                  CUFT                  458.57
  VAPOR PHASE VOLUME FRACTION                              0.97933
  VAPOR PHASE VOLUME              CUFT                    449.09
  LIQUID PHASE VOLUME             CUFT                    9.4805


BLOCK:  FEED-HEX MODEL: HEATER
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 INLET STREAM:          UNHEAT-F
 OUTLET STREAM:         FEED
 PROPERTY OPTION SET:   POLYNRTL  POLYMER NRTL / REDLICH-KWONG

                 ***  MASS AND ENERGY BALANCE  ***
                           IN            OUT        RELATIVE DIFF.
  TOTAL BALANCE
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    MOLE(LBMOL/HR)          196.539        196.539        0.00000
    MASS(LB/HR   )          13809.8        13809.8        0.00000
    ENTHALPY(BTU/HR  )     -0.343806E+08   -0.320444E+08   -0.679505E-01

               ***  CO2 EQUIVALENT SUMMARY ***
  FEED STREAMS CO2E            0.00000      LB/HR
  PRODUCT STREAMS CO2E         0.00000      LB/HR
  NET STREAMS CO2E PRODUCTION   0.00000      LB/HR
  UTILITIES CO2E PRODUCTION     523.626      LB/HR
  TOTAL CO2E PRODUCTION         523.626      LB/HR

                  ***  INPUT DATA  ***
 ONE    PHASE  TP  FLASH   SPECIFIED PHASE IS  LIQUID
 SPECIFIED TEMPERATURE              F                   410.000
 SPECIFIED PRESSURE                PSIA                 117.568
 MAXIMUM NO. ITERATIONS                                 30
 CONVERGENCE TOLERANCE                                    0.000100000



                  ***  RESULTS  ***
 OUTLET TEMPERATURE    F                            410.00
 OUTLET PRESSURE       PSIA                         117.57
 HEAT DUTY             BTU/HR                     0.23362E+07

               ***  ASSOCIATED  UTILITIES  ***

 UTILITY ID FOR ELECTRICITY                U-1
 RATE OF CONSUMPTION                  684.6661  KW
 COST                            53.0616  $/HR
 CO2 EQUIVALENT EMISSIONS              523.6261  LB/HR

BLOCK:  FEED-PUM MODEL: PUMP
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 INLET STREAM:         RAW-FEED
 OUTLET STREAM:        UNHEAT-F
 PROPERTY OPTION SET:   POLYNRTL  POLYMER NRTL / REDLICH-KWONG

               ***  MASS AND ENERGY BALANCE  ***
                          IN             OUT        RELATIVE DIFF.
  TOTAL BALANCE
    MOLE(LBMOL/HR)          196.539        196.539        0.00000
    MASS(LB/HR   )          13809.8        13809.8        0.00000
    ENTHALPY(BTU/HR  )     -0.343930E+08   -0.343806E+08   -0.361391E-03
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               ***  CO2 EQUIVALENT SUMMARY ***
  FEED STREAMS CO2E              0.00000      LB/HR
  PRODUCT STREAMS CO2E           0.00000      LB/HR
  NET STREAMS CO2E PRODUCTION    0.00000      LB/HR
  UTILITIES CO2E PRODUCTION      0.00000      LB/HR
  TOTAL CO2E PRODUCTION          0.00000      LB/HR

                  ***  INPUT DATA  ***
  OUTLET PRESSURE  PSIA                          120.000
  DRIVER EFFICIENCY                              1.00000

  FLASH SPECIFICATIONS:
  LIQUID PHASE CALCULATION
  NO FLASH PERFORMED
  MAXIMUM NUMBER OF ITERATIONS                        30
  TOLERANCE                                  0.000100000

                   ***  RESULTS  ***
  VOLUMETRIC FLOW RATE  CUFT/HR                  223.208
  PRESSURE CHANGE  PSI                           105.304
  NPSH AVAILABLE   FT-LBF/LB                     30.5435
  FLUID POWER  HP                                1.70943
  BRAKE POWER  HP                                4.88491
  ELECTRICITY  KW                                3.64268
  PUMP EFFICIENCY USED                           0.34994
  NET WORK REQUIRED  HP                          4.88491
  HEAD DEVELOPED FT-LBF/LB                       245.093

BLOCK:  MIXER    MODEL: MIXER
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 INLET STREAMS:        ADA        HDMA
 OUTLET STREAM:        RAW-FEED
 PROPERTY OPTION SET:   POLYNRTL  POLYMER NRTL / REDLICH-KWONG

               ***  MASS AND ENERGY BALANCE  ***
                         IN            OUT        RELATIVE DIFF.
  TOTAL BALANCE
    MOLE(LBMOL/HR)          196.539        196.539        0.00000
    MASS(LB/HR   )          13809.8        13809.8       0.131718E-15
    ENTHALPY(BTU/HR  )     -0.343930E+08   -0.343930E+08    0.216631E-15

               ***  CO2 EQUIVALENT SUMMARY ***
  FEED STREAMS CO2E              0.00000      LB/HR
```

PRODUCT STREAMS CO2E 0.00000 LB/HR
NET STREAMS CO2E PRODUCTION 0.00000 LB/HR
UTILITIES CO2E PRODUCTION 0.00000 LB/HR
TOTAL CO2E PRODUCTION 0.00000 LB/HR

*** INPUT DATA ***

TWO PHASE FLASH
MAXIMUM NO. ITERATIONS 30
CONVERGENCE TOLERANCE 0.000100000
OUTLET PRESSURE PSIA 14.6959